Synopsis of Research

Conducted under the 2000-2001 Northern Contaminants Program

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Foreword

This report provides a summary of the progress to date of research and monitoring studies on contaminants in northern Canada, and related education, communications and policy activities that were conducted in 2000-2001 under the auspices of the Northern Contaminants Program (NCP). The projects cover all aspects of northern contaminants issues, as outlined in the NCP blueprints, including human health, monitoring the health of Arctic peoples and ecosystems, and the effectiveness of international controls (abiotic monitoring and modelling, biotic monitoring, local contaminants concerns), education and communications, international policy and program management.

These projects were evaluated, as proposals, by external peer reviewers, technical review teams, a social/cultural review team, territorial/regional contaminants committees and the NCP Management Committee to ensure that they support the overall NCP objectives.

Further information about the NCP is available on the NCP Web site at www.inac.gc.ca/ncp.

Préface

Ce rapport résume l'avancement de recherches et d'études de surveillance portant sur les contaminants dans le Nord canadien, ainsi que d'activités connexes au sujet de l'éducation, de la communication et de la politique qui ont eu lieu en l'année 2000-2001. Ces études et activités ont été menées dans le cadre du Programme de lutte contre les contaminants dans le Nord (PLCN). Ces projets, tels que décrit dans les plans directeurs liés au programme, représentent tous les aspects portant sur les contaminants, incluant la santé humaine, la surveillance de la santé des habitants et des écosystèmes de l'Arctique et de l'efficacité des mesures de contrôle internationales (surveillance et modélisation milieux abiotiques, surveillance-milieux biotiques, préoccupations locales concernant les contaminants), l'éducation et la communication, la politique internationale et la gestion des programmes.

Ces projets ont été examinés par des pairs, des comités d'examen technique, un comité d'examen social et culturel, les comités territoriaux/régionaux sur les contaminants environnementaux, et le comité de gestion de la PLCN afin de s'assurer qu'ils répondent à l'ensemble des objectifs du programme de lutte contre les contaminants dans le Nord.

Pour de plus amples renseignements au sujet du programme de lutte contre les contaminants dans le Nord, visitez le site Web du PLCN au www.inac.gc.ca/ncp.

Introduction

The Northern Contaminants Program (NCP) was established in 1991 in response to concerns about human exposure to elevated levels of contaminants in fish and wildlife species that are important to the traditional diets of northern Aboriginal peoples. Early studies indicated that there was a wide spectrum of substances – persistent organic pollutants, heavy metals, and radionuclides – many of which had no Arctic or Canadian sources, but which were, nevertheless, reaching unexpectedly high levels in the Arctic ecosystem. The Program's key objective is *to reduce and, where possible, eliminate contaminants in northern traditionally harvested (country) foods while providing information that assists informed decision making by individuals and communities in their food use.*

Under the first phase of the NCP (NCP-I), research was focussed on gathering the data required to determine the levels, geographic extent and source of contaminants in the northern atmosphere, environment and its people, and the probable duration of the problem. The data enabled us to understand the spatial patterns and temporal trends of contaminants in the North, and confirmed our suspicions that the major sources of contaminants were other countries. The data, which included information on the benefits from continued consumption of traditional/country foods, was also used to carry out assessments of human health risks resulting from contaminants in those foods. Results generated through NCP-I are synthesized in the *Canadian Arctic Contaminants Assessment Report*.

Extensive consultations were conducted in 1997-1998 to find the common elements between the concerns and priorities of northern communities and the scientific needs identified as critical for addressing the issue of contamination in Canada's North. As a result, priorities for current and future research are based on an understanding of the species that are most relevant for human exposure to contaminants in the North, and geographic locations and populations that are most at risk.

In 1998-1999, the NCP began its second phase (NCP-II), which will continue until 2002-2003. NCP-II supports research designed to answer questions about the impacts and risks to human health that may result from current levels of contamination in key Arctic food species. To ensure a balanced assessment of the risks, an emphasis is placed on characterizing and quantifying the benefits associated with traditional diets. Communications activities are also emphasized and supported under NCP-II. Under the leadership of the northern Aboriginal organizations, the dialogue between northerners and the scientific community, which was initiated in NCP-I, continues to build awareness and an understanding of contaminants issues, and helps to support the ability to deal with specific contaminant issues at the local level.

In addition, the NCP effort to achieve international controls of contaminants remains strong in NCP-II. The legally binding POPs protocol, under the United Nations Economic Commission for Europe (UN ECE) Convention on Long-range Transboundary Air Pollution, has been successfully negotiated and was signed by 34 countries (including Canada) at the UN ECE Ministerial Conference in Aårhus, Denmark, in June 1998. Canada ratified this agreement in December 1998. Negotiations for a legally binding global instrument on POPs under the United Nations Environment Programme have now also been completed with the signing of the POPs Convention in Stockholm, Sweden, May 23, 2001. The Convention has been signed by more than 100 countries; Canada has signed and ratified the Convention. Cooperative actions under the Arctic Council, including the circumpolar Arctic Monitoring and Assessment Programme (AMAP) and the Arctic Council Action Plan (formally launched in October 2000), are continuing. NCP-II continues to generate the data that allows Canada to play a leading role in these initiatives.

The NCP is directed by a management committee that is chaired by the Department of Indian Affairs and Northern Development, and which includes representatives from four northern Aboriginal organizations (Council of Yukon First Nations, Dene Nation, Inuit Tapirisat of Canada and Inuit Circumpolar Conference), the Yukon, Northwest Territories and Nunavut Territorial Governments, Nunavik, and four federal departments (Environment, Fisheries and Oceans, Health, and Indian Affairs and Northern Development). The management committee is responsible for establishing NCP policy and research priorities and for final decisions on the allocation of funds. Three territorial contaminants committees in the Yukon, Northwest Territories and Nunavut (established in May 2000), and a regional contaminants committee in Nunavik support this national committee. Funding for the NCP-II's $5.4 million annual research budget comes from the Treasury Board and the four participating federal departments.

The NCP Operational Management Guide, developed in 2000-2001, and available on the NCP Web site (www.inac.gc.ca/ncp), provides a summary of the management structures and review processes used to effectively implement the NCP. The Guide explains the overall management structures currently used, the proposal review process and outlines a protocol to be used to publicly disseminate health and harvest information generated by the NCP. Background information on all NCP committees and review teams is also provided.

In 1998, the NCP Management Committee redesigned the NCP-Phase II for application under the 1999-2000 funding year. The two main initiatives undertaken were: 1) the development of blueprints that represent the long-term vision and strategic direction for NCP-II; and 2) the implementation of a more open and transparent proposal review process. This new management structure is designed to ensure that the NCP remains scientifically defensible and socio-culturally aware, while at the same time, achieving real progress in terms of the NCP's broad policy objectives.

Blueprints were developed for each of the four main NCP subprograms: i) Human Health, ii) Monitoring the Health of Arctic People and Ecosystems and the Effectiveness of International Controls, iii) International Policy, and iv) Education and Communications. The blueprints are used to provide the necessary guidance to project proponents for the development of proposals, as well as to peer reviewers, review teams and the NCP Management Committee for evaluating proposals. They are evolving documents that are reviewed at least annually.

Under a revamped proposal review process, the NCP Technical Committee was replaced with an external peer review process facilitated by review teams. The review of proposals is a two-pronged approach involving a scientific review by external peer reviewers, facilitated by technical review teams, and a socio-cultural review facilitated by a review team and the regional and Territorial Contaminants Committees (TCCs). Both sets of recommendations are considered by the Management Committee in making final funding decisions. Proposals submitted under the Education and Communications subprogram are evaluated by a review team and the TCCs. All peer reviewers, review teams and TCCs use evaluation criteria and the blueprints to review and rate proposals. Written consent from the appropriate northern community authority or national-level Aboriginal organization is required for all projects involving field work in the North and/or analyses of samples as a condition of approval for funding. The Social/Cultural Review Team ensures that each applicable proposal has a written consent form attached and sign by the applicable authority.

This report provides a summary of the progress to date of research and activities funded by the NCP in 2000-2001, the third year of NCP-II. It is a compilation of reports submitted by project teams, emphasizing the results of research and related activities that took place during the 2000-2001 fiscal year. The report is divided into chapters that reflect the broad scope of the NCP: Human Health; Monitoring the Health of Arctic Peoples and Ecosystems and the Effectiveness of International Controls (including abiotic monitoring and modelling, biotic monitoring and local contaminants concerns); Education and Communications; International Policy; and Program Management. Projects that are reported upon in this Synopsis of Research will be presented at the 11th Annual Northern Contaminants Program Results Workshop, to be held in Calgary, Alberta, September 25-27, 2001.

Human Health

Time-Related Changes in *trans*-Nonachlor, *trans*-Chlordane and Oxychlordane Levels in Rat Tissues

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Abstract

Oxychlordane and *trans*-nonachlor are bioaccumulative contaminants related to the pesticide chlordane that have been detected in the Arctic marine food chain. Recent studies indicate that *trans*-nonachlor and its major metabolite oxychlordane are among the most toxic chlordane-related contaminants, and that they are more toxic to female rats than male rats. The present study was designed to examine changes in *trans*-nonachlor and oxychlordane residue levels in male and female rats over time to clarify the relationships between residue accumulation, total body fat and changes in biomarkers for organ and cellular toxicity. Rats were exposed to either *trans*-nonachlor, oxychlordane or *trans*-chlordane by gavage for 28 consecutive days and necropsied 1, 28 and 56 days after the final dose. With the exception of a single female rat that died of oxychlordane toxicity at the end of the dosing period, no overt toxicity was observed in any treatment group. No visible lesions were observed in treated rats at necropsy, including the affected female. Analyses are in progress to measure changes in tissue residue levels and functional biomarkers in control and treated rats.

Key Project Messages

Although tissue and data analyses are still in progress, this study will address the following questions to provide key messages in the future:

1. Why is *trans*-nonachlor more toxic to female rats than to male rats?
2. How stable is *trans*-nonachlor in fat and other tissues? Oxychlordane is the primary metabolite of *trans*-nonachlor. Do oxychlordane levels in fat gradually increase and *trans*-nonachlor levels decline after exposure?
3. Is there a relationship between levels of *trans*-nonachlor and oxychlordane in tissues and toxicity.

especially after time has elapsed since the initial exposure?

4. Are there changes in tissue oxychlordane and *trans*-chlordane enantiomer ratios over time?

This will address fundamental questions about the relationship between the chirality of chlordane-related contaminants and their toxicity.

Objectives

Long-term

- To provide current information on the toxicity of chlordane metabolites and constituents which can be used to reduce uncertainty factors used in the calculation of tolerable daily intakes for chlordane-related food contaminants.

Short-term

1. To compare changes in *trans*-nonachlor, oxychlordane and *trans*-chlordane residue levels over time in male and female rat adipose, kidney and liver tissues.
2. To relate changes in tissue residue levels to sex, total body fat, and to biomarkers for toxicological changes.
3. To examine changes in tissue oxychlordane and *trans*-chlordane enantiomer ratios over time in male and female rats.

Introduction

Chlordane-related contaminants are present in traditional/country foods in the Arctic (Kuhnlein et al. 1995, Muir et al. 1988, O'Hara et al. 1999, Wade et al. 1997), and in human adipose tissue and breast milk (Dearth and Hites 1991a, Dewailly et al. 2000, Newsome et al. 1995, Newsome and Ryan 1999). The original pesticide was a mixture of many structurally related organochlorines (Dearth and Hites 1991b). The existing literature provides extensive toxicological data on the parent chlordane mixture (U.S. Department of Health and Human Services 1994). Recent studies have focussed on the toxicity of the individual chlordane contaminants present at the highest levels in foods and in human tissues and breast milk: the chlordane constituents *trans*-nonachlor and *cis*-nonachlor (Bondy et al. 2000) and the metabolite oxychlordane (Bondy et al. in progress). These studies indicate that *trans*-nonachlor and its major metabolite oxychlordane are the most toxic chlordane-related contaminants, and that *trans*-nonachlor is more toxic to female rats than male rats. As expected from the literature on chlordane, liver microsomal enzymes are induced by *trans*-nonachlor, *cis*-nonachlor and oxychlordane. Biomarkers indicative of changes in kidney function were altered in male rats but not in female rats treated with *trans*-nonachlor and *cis*-nonachlor. The present study was designed to address the following data gaps based on completed research:

1. Do *trans*-nonachlor levels in tissues gradually decline after exposure?
2. Do oxychlordane levels in tissues gradually increase if *trans*-nonachlor declines (indicating that *trans*-nonachlor is transformed to oxychlordane over time)?
3. Do differences in total body fat in female versus male rats account for higher levels of *trans*-nonachlor and oxychlordane in female rat adipose tissues?
4. What are the levels of *trans*-nonachlor and oxychlordane in kidneys, and are functional changes in male rat kidneys related to tissue residue levels?

This study also offers the opportunity to investigate the relationship between oxychlordane and *trans*-chlordane chirality and their toxicological properties. When a chiral chemical is synthesized a racemic mixture, or 1:1 ratio, of enantiomers is formed. However, there is some evidence that relative accumulation in animal tissues may differ for the (+) and (–) enantiomers of *trans*-chlordane and oxychlordane. Studies have shown that there are apparent species-dependent differences in the abundance of *trans*-chlordane enantiomers accumulating in tissues of fish from the Baltic, and that tissues from pigs given *cis*- or *trans*-chlordane have higher levels of (+)-oxychlordane (Müller and Buser 1994). To address questions about the relative accumulation of *trans*-chlordane and oxychlordane enantiomers, adipose tissues from rats treated with oxychlordane, *trans*-nonachlor and *trans*-chlordane will be analyzed for oxychlordane enantiomers. In addition, adipose from rats treated with *trans*-chlordane will be analyzed for *trans*-chlordane enantiomer residues. These analyses will provide information on the following: potential changes in enantiomer residue levels in rat adipose tissues over time; potential sex-related differences in enantiomer accumulation in adipose tissues.

Activities in 2000-2001

The animal phase of this study was initiated in September 2000 and was completed in December 2000. Briefly, groups of male and female Sprague-Dawley rats were exposed to either *trans*-nonachlor, oxychlordane or *trans*-chlordane by gavage for 28 consecutive days (Table 1). *Trans*-chlordane, which is a major component of the parent chlordane mixture, was included for comparison to published studies. At the end of the exposure period one-third of each group were necropsied, as indicated in

Table 1. Summary of test groups for each necropsy (1 day, 28 days and 56 days after dosing)

	Number of rats/group		
Dose group[a]	Necropsy 1 (Oct. 2000)	Necropsy 2 (Nov. 2000)	Necropsy 3 (Dec. 2000)
Control (corn oil)	18[b,c]	16	16
Trans-nonachlor (2.5 mg·kg^{-1})	16	16	16
Oxychlordane (2.5 mg·kg^{-1})	18[c]	16	16
Trans-chlordane (2.5 mg·kg^{-1})	16	16	16
Total	68	64	64

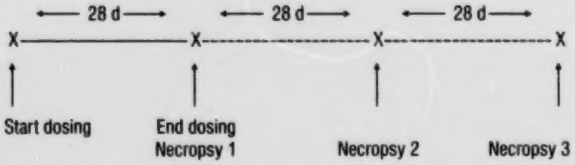
[a] Total rats required, including eight quality controls: 204.

[b] Groups will be composed of eight males and eight females, except where designated[c].

[c] Ten control and oxychlordane-treated female rats will be required for the first necropsy because data from these rats will also be used to supplement previous oxychlordane studies. We have previously exposed female rats to 1 and 10 mg·kg^{-1} oxychlordane. These rats will be given a full toxicological evaluation, which requires a minimum of 10 rats per sex.

Figure 1. The remaining rats were necropsied 28 and 56 days after the final dose, according to the time line in Figure 1. Tissue and data analyses will proceed throughout 2001. The following endpoints will be measured: liver, kidney and adipose tissue residue levels of *trans*-nonachlor, oxychlordane or *trans*-chlordane; oxychlordane and *trans*-chlordane enantiomer ratios in tissues from treated rats; total body fat; renal function (clinical biomarkers, organic ion transport in kidney slices); and liver function (clinical biomarkers).

Figure 1. Time line for dosing and necropsies of *trans*-nonachlor, oxychlordane and *trans*-chlordane-treated rats



Results

No visible lesions were seen at necropsy in any group. There was one death due to oxychlordane toxicity. A female rat was euthanised after her last dose of oxychlordane (2.5 mg·kg^{-1}) but prior to her scheduled necropsy when she lost > 15 g body weight in a 24-hour period. This is consistent with large weight losses seen in previous studies in female rats receiving 10 mg·kg^{-1} oxychlordane. There were no visible lesions at necropsy in the affected rat.

Discussion and Conclusions

Previous oxychlordane studies indicated that 10 mg oxychlordane·kg body weight^{-1}·day^{-1} was toxic to female rats after three consecutive oral doses, but that 1 mg oxychlordane·kg bw^{-1}·d^{-1} was not toxic after 28 consecutive oral doses (G. Bondy, unpublished observations). The dose used in this study was 2.5 mg oxychlordane·kg bw^{-1}·d^{-1} with which there was one fatality (in 30 female rats) after 28 consecutive doses. Taken together, the data indicate that the dose response curve for oxychlordane is steep in rats, with only a small difference between a fatal and a non-toxic dose. Further conclusions based on this study await the completion of tissue and data analyses.

Expected Project Completion Date

Tissue analyses: December 2001
Data summary and statistical analyses: April 2002

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Dietary Effects on Methylmercury Toxicity in Rats

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Abstract

This ongoing project is designed to study the possible effects of dietary modulations on mercury toxicity. Mercury accumulates in fish and marine mammals. Therefore, Inuit who consume a traditional diet may be exposed to higher levels of mercury. However, the traditional diet also contains rich sources of beneficial nutrients such as protein, oil, vitamins and minerals. There is some evidence that these nutrients may protect against mercury toxicity. This project will study effects of these nutrients on mercury toxicity by feeding rats diets containing different nutrient compositions. Results will be useful for characterization of the health risk of mercury in the Inuit diet.

Key Project Messages

1. There is some evidence that nutrients in the traditional Inuit diet such as protein, oil, vitamins and minerals may protect against mercury (Hg) toxicity.
2. This project is studying the effects of these nutrients on Hg toxicity by feeding rats diets containing different nutrient compositions.
3. Results from this project are not yet available.

Objectives

Overall objective

- To study the effects of dietary factors on methylmercury (MeHg) toxicity.

Specific objectives

1. To study the effects of fish proteins on MeHg kinetics and toxicity.
2. To study the effects of omega-3 fatty acid, particularly fish oil and seal oil on MeHg kinetics and toxicity.

Introduction

Elevated levels of Hg have been reported in terrestrial, freshwater and marine biota in the Canadian North (Jensen et al. 1997). Ringed seal (*Phoca hispida*), the most abundant marine mammal species in the Canadian Arctic, is a major component and the major source of Hg in the

Inuit traditional diet (Chan et al. 1995). Elevated levels of Hg, i.e. exceeding the Health Canada consumer guideline (for fish flesh) of 0.5 $\mu g \cdot g^{-1}$ wet wt, are commonly found in ringed seal meat (Chan 1998). Results of the Broughton Island study in 1988 showed that the Hg intake levels of 83% of the respondents exceeded the provisional tolerable weekly intake of 5 $\mu g \cdot kg^{-1} \cdot week^{-1}$ (Chan et al. 1997). The Inuit diet also contains high concentrations of selenium and omega-3 fatty acids.

Dietary factors influence the whole-body retention of orally administered MeHg and mercuric Hg. In mice, Landry et al. (1979) concluded that milk increased MeHg absorption from the gastro-intestinal tract. This could have resulted from an effect of milk on the enterohepatic circulation and/or de- and re-methylation of Hg in the intestine since the absorption rate of MeHg was close to 100% in all cases. Wheat bran added to semi-synthetic diets decreased, whereas cellulose increased the retention of orally administered MeHg chloride in mice (Rowland 1986). A high-protein, low-fat diet decreased the retention of orally administered MeHg in mice (Rowland 1984). Diets containing fish protein, a good source of both selenium and sulphur amino acids, decreased the toxicity of MeHg in mice compared with diets containing casein (Ohi et al. 1976). Hojbjerg et al. (1992) found that the whole-body retention was significantly reduced when mice were fed with a diet containing 50% cod liver oil compared with mice fed with 50% coconut oil. However, the relative deposition of Hg was significantly higher in all organs of mice fed a diet containing 20% energy from cod liver oil compared with mice fed a diet containing 20% energy from soya oil.

Activities in 2000-2001

Two animal feeding experiments have been completed.

Experiment 1: Effect of dietary proteins

Eighteen male Sprague-Dawley rats (initial body weights: 150 to 170 g) were fed one of three isocaloric, starch-based, semi-purified diets containing 20% wt of either (a) fish protein, (b) whey protein, or (c) casein for 4 weeks before the dosing experiment. MeHg was administered for 14 days by gavage at three dose levels: (1) control, (2) 1 $mg \cdot kg^{-1} \cdot day^{-1}$ or (3) 3 $mg \cdot kg^{-1} \cdot day^{-1}$.

Experiment 2: Effect of dietary lipids

Thirty male rats were fed one of five isocaloric, starch-based, semi-purified diets containing 20% wt of either (a) seal oil, (b) fish oil, (c) DHA oil, (d) soya oil, or (e) lard, for 4 weeks before the dosing experiment. MeHg was administered for 14 days by gavage at three dose levels: (1) control, (2) 1 $mg \cdot kg^{-1} \cdot day^{-1}$ or (3) 3 $mg \cdot kg^{-1} \cdot day^{-1}$.

For both Experiments 1 and 2, rats were housed in pairs in plastic cages under conditions meeting the requirements of the Canadian Council for Animal Care. During the course of dosing, the rats remained on the three semi-purified diets and the general metabolic indices were monitored. Faeces and urine were collected on Day 0, 6 and 13 for analysis of Hg levels and urinary constituents as markers of kidney damage, repectively.

Animals were sacrificed, necropsied, and parts of liver, kidney and brain tissues were excised and stored at −80°C until analyzed for Hg levels and various toxicological parameters including gene transcription analysis. Fresh kidney slices were used to determine organic ion transport as an index of MeHg induced nephrotoxicity. Tissues were stored in formalin for histopathological and immunohistochemical assessment.

The following data have been collected and are currently being analyzed: body weights, organ weights, food consumption, serum biochemistry, hematology parameters and various nephrotoxicity related parameters. Hg analysis and the following specific tests for oxidative stress are being conducted:

- in vitro mitochondria superoxide radical generation in brain mitochondria,
- plasma and tissue (brain, kidney and liver) lipid peroxide concentrations,
- brain, kidney and liver oxidized and reduced glutathione concentrations, and
- analysis of the oxidative DNA damage related 8-hydroxy-2'-deoxyguanosine DNA adduct.

Tissues are being processed for routine histopathology, and immunohistochemical and transcriptional analysis to assess expression of protein products and transcripts of a variety of toxicity and stress related genes.

Results

The analysis is in progress and there are no results to report at this time.

Expected Project Completion Date

December 2001

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Estimation of Site-Specific Dietary Exposure to Contaminants in Two Inuit Communities

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Abstract

The Centre for Indigenous Peoples' Nutrition and Environment conducted a dietary survey for 18 Inuit communities in the Northwest Territories and Nunavut in 1998 to 2000. A preliminary contaminant exposure assessment was conducted using contaminant data from an existing database. A more site-specific exposure assessment was conducted for two communities – Chesterfield Inlet and Igloolik – that had among the highest risks of exposure according to the preliminary estimate. A total of 64 samples of traditional/country food that are either the major contaminant contributors or were missing from the database were collected and their contaminant concentrations were measured. The new estimates for organochlorine intake are lower than the previous estimates. The mean intakes for chlordane and toxaphene are still higher than the provisional tolerable daily intake (PTDI) and the revised 95th centile intake levels exceed the PTDI by about 10-fold. The revised mean daily heavy metal intake levels are similar to the previous estimate. The revised mean mercury intake is higher than the PTDI in both communities. The intake of chlordane, toxaphene and mercury in these two communities remains a concern.

Key Project Messages

1. The organochlorine (OC) intake levels in Chesterfield Inlet and Igloolik are lower than previously estimated.
2. The intake of chlordane, toxaphene and mercury in these two communities remains a concern.

Objectives

Overall objective

- To ascertain the results of a preliminary exposure assessment conducted based on the Centre for Indigenous Peoples' Nutrition and Environment (CINE) dietary survey. This is to be achieved by collecting and analyzing food samples from two Inuit communities that have been identified as having among the highest risks of exposure and by conducting a site-specific quantitative estimation of contaminant exposure.

Specific objectives

1. To identify two Inuit communities that show the highest risk of contaminant exposure according to a

preliminary exposure assessment based on the CINE dietary survey.

2. To collect food samples that are the major contributors to contaminant intake from these two communities.
3. To analyze the contaminant concentrations (heavy metals and/or organics) in these food samples.
4. To estimate the contaminant intake in these two communities by combining the food contaminant concentration and the food intake data.
5. To communicate the risk of exposure to these two communities.
6. To validate results of the preliminary exposure assessment using results of this detailed study.

Introduction

CINE has collected dietary information from 18 Inuit communities and has completed a project titled "Assessment of Dietary Benefit:Risk in Inuit Communities" (Kuhnlein et al. 2000). One of the objectives of this project is to define the levels of dietary exposure to contaminants. A typical daily contaminant intake level can be calculated by multiplying the food intake data ($g \cdot day^{-1}$) by the mean concentration of the food group ($\mu g \cdot g^{-1}$). To do that, we have to obtain data for contaminant concentrations in all the food items that have been mentioned in the dietary recalls in each of the 18 communities. It is not possible logistically to collect so many samples or to cover the laboratory expenses. Instead, we have used the contaminant data from our database as described in Chan (1998). The data are average values of the levels of contaminants in fish and wildlife collected from different regions in northern and Arctic Canada over the last 10 years. However, since the contaminant data used for this estimation are not collected specifically from any of these communities, the generated data are only estimates of *potential* intake but not *actual* intake. It is important to estimate the *actual* intake, particularly in those communities that show potentially high intake levels.

Activities in 2000-2001

We discussed the details of this study with representatives from all the communities that participated in the dietary study, the Inuit Tapirisat of Canada, and the Department of Health and Social Services of the Government of Nunavut. Igloolik and Chesterfield Inlet, two communities with estimated contaminant intakes among the highest, were invited to participate in this study. Local assistants were hired in each of the two communities with help from the Hunters and Trappers Associations. A total of 64 traditional/country food samples that are either the major contaminant contributors or samples for which we did not have data were collected and their contaminant concentrations were measured. Exposure assessment was recalculated using the new information.

Results

Concentrations of the seven major groups of OCs including chlordane (CHL), chlorobenzene (CBZ), DDT, hexachlorocyclohexane (HCH), mirex (MIR), total polychlorinated biphenyls (PCBs) (the sum of 51 congeners), and toxaphene (TOX) in the collected samples are shown in Table 1. Highest concentrations are found in marine mammal blubbers. Concentrations of the four heavy metals (arsenic [As], cadmium [Cd], lead [Pb], mercury [Hg]) and selenium (Se) are shown in Table 2. Walrus blubber and Arctic char had the highest As concentrations. Highest concentrations of Cd and Hg were found in marine mammal livers, and marine mammal muktak are richest in Se.

The revised mean daily intake and the 95th centile intake of OCs are compared to the previous estimate and the provisional tolerable daily intake (PTDI) levels in Table 3. The new estimates are all lower than the previous estimates, particularly for toxaphene. The mean intakes for CHL in Chesterfield Inlet and CHL and TOX in Igloolik are still higher than the PTDI, but the magnitude has decreased from four to 20 times to about two to five times. The previous 95th centile exceeded the PTDI by 100-fold, however, the revised intake levels exceed the PTDI by about 10-fold.

The revised mean daily heavy metal intake levels are very similar to the previous estimates (Table 4). The revised mean Hg intake has increased in Chesterfield Inlet but the revised Pb intake has decreased in Igloolik. The revised Hg intake is higher than the PTDI in both communities. The revised 95th centiles are very similar to the previous estimates.

Discussion

It is unfortunate that not all the major food items or the desirable number of replicates of samples were available during the sampling period. However, samples collected specifically from the two communities have confirmed the fact that various contaminants are present in various parts of species at elevated levels because of the effects of bioaccumulation and biomagnification. The only exception is the elevated levels of Pb found in a caribou flesh sample (> 20 $\mu g \cdot g^{-1}$). It is obvious that ammunition is the source. This data is not used to estimate exposures

Table 1. Concentrations of organochlorines in food samples collected from Chesterfield Inlet and Igloolik (ng·g^{-1} wet weight)

Species	Part	Preparation	CHL	CBZ	DDT	HCH	MIR	PCB	TOX
Chesterfield Inlet									
Beluga	muktuk, skin	raw	143	78	278	41	2	281	248
Caribou	bone marrow	raw	0	3	3	10	0	16	0
Caribou	bone marrow	aged	5	51	123	9	16	22	0
Caribou	bone marrow	aged	1	4	3	2	1	2	257
Caribou	bone marrow	raw	7	40	212	1	0	40	0
Caribou	bone marrow	raw	0	2	2	0	0	0	0
Lake trout	flesh	raw	3	1	10	0	0	4	64
Lake trout	flesh	raw	3	0	16	0	0	5	33
Lake trout	flesh	raw	3	1	6	0	0	4	0
Polar bear	flesh, ribs	raw	2	0	5	1	0	2	45
Seal	flesh	raw	5	0	19	1	1	13	26
Walrus	flipper	aged	4	0	8	2	1	41	90
Walrus	flesh, ribs	raw	2	0	5	1	0	6	45
Walrus	flesh	aged	5	0	10	1	2	11	47
Walrus	flesh	raw	9	0	13	7	2	46	84
Walrus	muktuk, skin	raw	610	2	4332	21	166	8250	449
Walrus	flesh, with fat	raw	30	43	29	8	0	504	49
Walrus	flesh	raw	22	1	95	3	5	253	N/A[1]
Igloolik									
Arctic char	flesh	raw	2	0	7	3	1	1	0
Arctic char	flesh	raw	2	3	20	2	7	5	0
Arctic char	flesh	raw	1	0	4	1	0	2	0
Arctic char	flesh	raw	4	2	22	2	0	3	30
Arctic char	flesh	raw	5	1	27	2	0	3	25
Beluga	muktuk, skin	frozen	119	40	118	22	1	196	181
Beluga	muktuk, skin	frozen	130	48	300	8	4	203	182
Beluga	blubber	frozen	1373	662	1057	163	7	1436	1495
Beluga	blubber	frozen	919	354	1758	53	23	1279	1031
Caribou	flesh, chest	raw	9	0	57	2	0	3	69
Caribou	flesh	raw	1	0	5	0	0	0	0
Caribou	flesh	raw	2	0	9	0	0	0	25
Caribou	flesh	raw	2	0	15	1	0	8	43
Caribou	flesh	raw	3	1	35	0	1	13	20
Narwhal	oil	raw	26	11	40	6	0	39	271
Ringed seal	liver	raw	3	1	16	2	0	7	18
Ringed seal	liver	raw	3	1	15	4	1	6	29
Ringed seal	flesh, ribs	raw	9	2	23	28	1	17	20
Ringed seal	flesh, spine	raw	2	0	16	1	0	4	21
Ringed seal	flesh, ribs	raw	9	2	20	9	1	27	20

Table 1 continued

Table 1. Concentrations of organochlorines in food samples collected from Chesterfield Inlet and Igloolik (ng·g^{-1} wet weight)

Species	Part	Preparation	CHL	CBZ	DDT	HCH	MIR	PCB	TOX
Ringed seal	oil	raw	91	27	127	161	0	239	281
Ringed seal	flesh	raw	1	0	7	14	0	0	116
Ringed seal	flesh	raw	6	14	22	13	0	10	N/A
Walrus	liver	raw	3	0	14	0	0	3	19
Walrus	blubber	raw	7	0	18	6	0	9	257
Walrus	blubber	raw	6	0	25	7	3	11	240
Walrus	liver	raw	7	0	29	1	0	4	41
Walrus	liver	raw	2	1	7	1	0	18	45
Walrus	blubber	raw	5	0	21	8	1	15	220
Walrus	liver	raw	6	0	32	2	1	1	45
Walrus	blubber	raw	7	0	16	2	1	16	243
Walrus	blubber	raw	54	2	21	20	3	122	109

[1] Not analyzed

as it is not representative of the typical Pb levels found in this food. However, the issue of Pb in game meat may need further investigations.

It is reassuring to see that the measured OC concentrations are lower than the average concentrations in the literature (Chan 1998), particularly for CHL and TOX. For example, average concentrations of CHL in walrus blubber was 2203 ng·g^{-1} whereas the revised concentration was 19 ng·g^{-1}. Similarly, TOX concentration in beluga blubber was revised from 8568 ng·g^{-1} to 1263 ng·g^{-1}. In consequence, the estimated daily intake is lower than reported in the preliminary assessment. However, the message remains the same – the intake of CHL, TOX and Hg in these two communities remains a concern, particularly among the frequent consumers of marine mammals.

Overall, results of this study have confirmed that the preliminary risk assessment (Kuhnlein et al. 2000) is valid. The main reason for the over-estimate of the preliminary study was likely due to the skewness of the contaminant data reported in the literature, i.e. the average value is elevated because of some extremely high concentrations reported for some animals. A typical example is walrus blubber; the collected samples had OC concentrations at about 100 times lower than the average value reported in the literature.

Results of the study will be released following the procedures described in the document titled *Protocol for Contaminants Health and Harvest Information Release in the Yukon, Northwest Territories and Nunavut* (Northern Contaminants Program 2001). Data will be submitted to the QA/QC officer of Northern Contaminants Program for validation and to the Nunavut Environmental Contaminants Committee for risk assessment and risk management. Interpretation of the results will be conducted in consultation with the Chief Medical Officer of Health, Department of Health and Social Services, Government of Nunavut. Workshops will be held in both communities in the fall 2001 in cooperation with the Inuit Tapirisat of Canada and the Department of Health and Social Services, Government of Nunavut.

Expected Project Completion Date

December 2001

Table 2. Concentrations of heavy metals and selenium in food samples collected from Chesterfield Inlet and Igloolik ($ng \cdot g^{-1}$ wet weight)

Species	Part	Preparation	As	Cd	Hg	Pb	Se
Chesterfield Inlet							
Beluga	blubber	raw	511	4	bdl[1]	bdl	bdl
Beluga	muktuk, skin	raw	97	17	252	bdl	6311
Caribou	bone marrow	raw	bdl	bdl	bdl	bdl	17
Caribou	bone marrow	aged	bdl	bdl	8	bdl	32
Caribou	bone marrow	aged	bdl	bdl	5	bdl	25
Caribou	bone marrow	raw	bdl	bdl	bdl	bdl	22
Caribou	bone marrow	raw	bdl	bdl	bdl	bdl	24
Caribou	bone marrow	raw	bdl	bdl	bdl	bdl	bdl
Caribou	flesh	raw	bdl	5	11	bdl	bdl
Cranberries, low bush	berries	raw	bdl	bdl	bdl	bdl	bdl
King eider duck	eggs	boiled	126	bdl	330	bdl	564
King eider duck	eggs	boiled	123	bdl	448	bdl	544
Lake trout	flesh	raw	bdl	bdl	762	bdl	351
Lake trout	flesh	raw	bdl	bdl	337	bdl	288
Lake trout	flesh	raw	bdl	bdl	496	bdl	427
Lake trout	flesh	raw	bdl	bdl	604	bdl	214
Polar bear	flesh, ribs	raw	bdl	10	113	bdl	273
Seal	flesh	raw	138	bdl	151	bdl	202
Walrus	flipper	aged	114	30	25	67	256
Walrus	flesh, ribs	raw	106	68	97	bdl	871
Walrus	flesh	aged	210	40	72	347	1440
Walrus	flesh	raw	90	75	134	13	627
Walrus	flesh	raw	83	110	116	100	1238
Walrus	flesh and fat	raw	172	246	258	239	2971
Walrus	kauk (mattak)	raw	168	23	15	bdl	bdl
Walrus	kauk (mattak)	raw	200	24	bdl	bdl	bdl
Igloolik							
Arctic char	flesh	raw	522	bdl	23	bdl	85
Arctic char	flesh	raw	485	bdl	28	bdl	127
Arctic char	skin	raw	1136	bdl	12	bdl	246
Arctic char	flesh	raw	416	bdl	37	bdl	90
Arctic char	skin	raw	551	bdl	10	bdl	171
Arctic char	flesh	raw	891	bdl	63	bdl	46
Arctic char	skin	raw	848	bdl	11	bdl	277
Arctic char	flesh	raw	135	bdl	26	bdl	187
Beluga	muktuk, skin	frozen	61	bdl	320	bdl	1467
Beluga	muktuk, skin	frozen	69	bdl	368	bdl	2503
Caribou	flesh, chest	raw	bdl	bdl	5	bdl	43

Table 2 continued

Table 2. Concentrations of heavy metals and selenium in food samples collected from Chesterfield Inlet and Igloolik ($ng \cdot g^{-1}$ wet weight)

Species	Part	Preparation	As	Cd	Hg	Pb	Se
Caribou	flesh	raw	28	bdl	bdl	bdl	116
Caribou	flesh	raw	18	bdl	bdl	bdl	101
Caribou	flesh	raw	29	bdl	bdl	bdl	67
Caribou	flesh	raw	23	bdl	bdl	bdl	86
Caribou	flesh	raw	bdl	bdl	bdl	26 528	bdl
Caribou	tongue	raw	bdl	3	7	bdl	bdl
Ringed seal	liver	raw	18	5706	8283	bdl	2684
Ringed seal	liver	raw	29	334	267	bdl	541
Ringed seal	flesh, ribs	raw	60	bdl	bdl	bdl	79
Ringed seal	flesh, spine	raw	28	bdl	96	bdl	178
Ringed seal	flesh, ribs	raw	260	22	22	bdl	106
Ringed seal	blood	raw	112	12	104	bdl	1328
Ringed seal	blood	raw	137	23	115	bdl	1429
Ringed seal	flesh	boiled	577	bdl	121	bdl	571
Ringed seal	flesh	raw	67	bdl	87	bdl	271
Ringed seal	flesh	raw	102	5	105	bdl	241
Ringed seal	liver	raw	103	408	454	bdl	240
Ringed seal	liver	raw	242	395	418	bdl	594
Snow goose	flesh	raw	bdl	bdl	bdl	bdl	bdl
Walrus	liver	raw	61	10645	4825	104	3396
Walrus	blubber	raw	796	bdl	4939	bdl	155
Walrus	blubber	raw	3954	24	bdl	bdl	113
Walrus	liver	raw	85	13600	961	bdl	1987
Walrus	liver	raw	70	6354	3546	bdl	2683
Walrus	blubber	raw	1345	56	bdl	bdl	182
Walrus	liver	raw	100	8025	1858	104	1912
Walrus	blubber	raw	2414	48	bdl	bdl	158

[1] Below detection limits (As = 17 $ng \cdot g^{-1}$, Cd = 9 $ng \cdot g^{-1}$, Hg = 5 $ng \cdot g^{-1}$, Pb = 61 $ng \cdot g^{-1}$, Se = 24 $ng \cdot g^{-1}$)

Table 3. **Estimated daily intake of organochlorines ($\mu g \cdot kg^{-1} \cdot d^{-1}$) using previous and revised data**

OCs	PTDI	Previous mean	Revised mean	Previous 95th centile	Revised 95th centile
Chesterfield Inlet (n = 115)					
CHL	0.05	0.29	0.12	1.93	0.79
CBZ	0.27	0.11	0.08	0.47	0.40
DDT	20.00	0.51	0.25	2.46	1.84
HCH	0.30	0.06	0.02	0.28	0.15
MIR	0.07	0.01	0.00	0.08	0.02
PCB	1.00	0.63	0.30	3.64	2.42
TOX	0.20	1.01	0.17	7.95	1.23
Igloolik (n = 107)					
CHL	0.05	1.02	0.22	5.95	1.27
CBZ	0.27	0.13	0.08	1.04	0.61
DDT	20.00	1.14	0.59	7.17	1.15
HCH	0.30	0.11	0.62	0.49	0.25
MIR	0.07	0.01	0.02	0.06	0.06
PCB	1.00	1.88	0.45	12.31	2.23
TOX	0.20	5.94	0.52	31.82	2.29

Table 4. **Estimated daily intake of heavy metals ($\mu g \cdot kg^{-1} \cdot d^{-1}$) using previous and revised data**

Heavy Metal	PTDI	Previous mean	Revised mean	Previous 95th centile	Revised 95th centile
Chesterfield Inlet (n = 115)					
As	2	0.4	0.4	3.9	3.9
Cd	1	0.3	0.3	0.9	0.9
Hg	0.7	0.5	1.1	3.8	2.8
Pb	3.6	1.8	1.2	8.0	6.0
Igloolik (n = 107)					
As	2.0	1.3	1.9	5.2	5.4
Cd	1.0	0.9	0.8	4.2	5.6
Hg	0.7	1.2	1.1	4.0	5.0
Pb	3.6	3.6	0.5	11.2	3.2

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Effects of Prenatal Exposure to Organochlorines and Mercury on the Immune System of Inuit Infants

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Abstract

This project is nested in the ongoing PCBs and Infant Development Study. The objective is to examine the effects of prenatal and postnatal exposure to organochlorines and mercury on the incidence of infection and immune system parameters during the first year of life. A total of 244 mothers have agreed to participate in the study and 190 infant medical charts should be available for review. Of these, a subgroup of 115 infants were selected for the immunological analysis. So far, 130 charts have been reviewed and biological analyses (cytokines [IL-10 and TNF-α] and Hib antibodies) were performed on 60 samples. In preliminary statistical analysis, there seems to be an association between prenatal exposure to polychlorinated biphenyls and incidence of infections. However, only crude analyses were performed and no conclusion can yet be drawn since potential confounders were not considered. Data collection will continue until September 2002 and the project will be completed in March 2003.

Key Project Messages

1. This study investigates possible detrimental effects on the immune system of Inuit infants which may be induced by prenatal and postnatal exposure to persistent environmental contaminants such as organochlorine (OC) compounds and heavy metals.
2. A total of 190 infant medical charts will be reviewed. Of them, a subgroup of 115 infants were selected for the assessment of immune system functions. So far,

130 charts have been reviewed and biological analyses were performed on 60 samples.

3. Data collection is still ongoing. Only preliminary statistical analyses have been performed and no definitive results are available yet. The project will be completed in March 2003.

Objectives

Overall objective

- To examine the effects of prenatal and postnatal exposure to OCs and mercury (Hg) on the immune system of Inuit infants from birth to 12 months of age.

Specific objectives

1. To assess prenatal and postnatal exposure to OCs and Hg.
2. To measure some immunological parameters (humoral and cellular immunity).
3. To determine incidence of infection.
4. To assess vitamin A status.

Introduction

Substantial information concerning the contamination of northern marine food by persistent organic pollutants (POPs) and heavy metals is now available (Barrie et al. 1992, Braune et al. 1999, Bright et al. 1995, Burkow and Kallenborn 2000, Lockhart et al. 1992, Muir et al. 1999, Muir et al. 1992, Thomas et al. 1992). Chemicals such as pesticides (dieldrin, mirex, toxaphene), industrial compounds and by-products of industrial processes (hexachlorobenzene, polychlorinated biphenyls [PCBs], polychlorodibenzo-*p*-dioxins [PCCDs], polychlorodibenzofurans [PCDFs), as well as heavy metals (inorganic and organic Hg, lead, cadmium), have been emitted throughout the world for years. Many regulatory actions have been taken since the late 1970s to limit their emission but they are still released due to improper storage and ongoing use in certain parts of the world.

Prenatal and postnatal exposures to OCs, in particular dioxin-like compounds, produce a wide variety of toxic effects in animals and humans. Alterations of T-cell subsets, of serum immunoglobulin A (IgA) and IgM concentrations, of delayed-type hypersensibility and of complement activation have all been documented in rodents, primates and human (Chang et al. 1982, Esser and Welzel 1993, Hoffman et al. 1986, Holsapple et al. 1984, Lu and Wu 1985, Neubert et al. 1992, Thomas and Hinsdill 1979, Tryphonas et al. 1991a, Tryphonas et al. 1991b, White et al. 1986). The development of the immune system in utero and during infancy is particularly sensitive to immunotoxic products such as OCs. High exposure during early life could lead to permanent defects of the immune system and thus decrease resistance to infectious agents (Badesha et al. 1995).

Organic and inorganic Hg possess cytotoxic activities for cellular components of the immune system in several species of rodents. Methylmercury (MeHg), a form of organic Hg, can alter non-specific defense mechanisms, such as the inhibition of natural killer cell activity in rats and mice. It also decreases the expression of certain activation markers of T cells (HLA-Dr, IL-2R) (Moszczynski 1997). Moreover, it has been well demonstrated that MeHg can affect the functions of B cells and therefore reduce the humoral mediated response (Moszczynski 1997). Exposure to inorganic Hg induces allergies and autoimmune problems in hypersensitive individuals (Bagenstose et al. 1999).

The high incidence of infectious diseases (in particular meningitis, broncho-pulmonary and middle ear infections) in infants and children from Nunavik has been known for many years (Dufour 1988, Proulx 1988). Middle ear infections are of special concern since approximately 25% of school age Inuit children suffer some kind of hearing loss (Julien et al. 1987). Because of the immunotoxic effects of OCs and MeHg, particularly after perinatal exposure, we hypothesized that part of the high infection incidence among Inuit infants could be related to the high maternal body burden of these contaminants.

This study is nested in the ongoing PCBs and Infant Development Study and will involve approximately 190 Inuit mothers and their newborns. It investigates possible detrimental effects on the immune system of Inuit infants that may be induced by prenatal and postnatal (breast feeding) exposure to OCs and Hg. Immune system function is evaluated using several immunological markers including the level of antibody produced by the infant following *Haemophilus influenza* immunization, the level and function of the complement system and its components, and the level of some Th1 and Th2 cytokines. Vitamin A concentration is also evaluated in the mother and the infant since striking similarities exist between symptoms of high dioxin-like compound exposure and vitamin A deficiency. Finally, infectious episodes are recorded over the first 12 months of life and the possible relationship between recurrent infections and high OC burdens will be analyzed. Results of this research could be used by intervening institutions for the purpose of risk prevention and management, by other researchers and by the public.

Activities in 2000-2001

The recruitment of participants ended in April 2001. A total of 244 mothers have agreed to participate in the study. Considering potential miscarriages, mortality and withdrawal from the study, we expect to review 190 infant medical charts. A subgroup of 115 infants were selected for the immunological analysis (cytokines, complement and antibody titer).

Two trips (October 2000 and April 2001) to Puvirnituq, Inukjuaq and Kujjuuarapik were done to coordinate the collection and shipping of biological samples as well as to review the medical charts of the participants. So far, 130 medical charts have been reviewed.

A second fieldworker in Inukjuaq was recruited and trained. She will be helping as well as replacing the other field worker whenever it is needed.

Laboratory analyses have begun. Cytokines (IL-10 and TNF-α) and Hib antibodies were analyzed in 60 blood samples.

The construction of the database and the data entry and coding have begun and will continue throughout 2001-2002.

Results

We could only perform crude preliminary analyses on some of the available data. Concerning the immunological analysis, only IL-10 and Hib results for infants at 6 months were available in the database. Table 1 shows the mean levels of IL-10 concentration and Hib titer at 6 months of age according to the maternal blood level of the PCB congener 153 (the most frequent) on a lipid basis. The maternal PCB level was dichotomized; the mothers with PCB levels below the median were put in the category "low PCB exposure" and the ones with concentrations above the median were put in the category "high PCB exposure." There was no difference for the mean IL-10 concentration. Hib titers were higher in the exposed group.

Eighty-nine infant medical charts that have been reviewed were partially summarized in the database. Table 2 shows the mean number of reported infectious disease episodes for the first year of life according to the prenatal PCB exposure (maternal PCB congener 153 on a lipid basis). With the exception of otitis and tonsillitis, the mean number of infections was higher in the exposed group.

We then computed the relative risk of the various infection types during the first year of life according to the prenatal PCB exposure (Table 3). Again, with the exception of otitis and tonsillitis, the risk of experiencing frequent infectious episodes was higher in the exposed group. The association between PCB exposure and the risk of having at least one episode of pneumonia was significant ($p = 0.025$).

Discussion and Conclusions

The results presented in this synopsis of research are preliminary. Only crude associations are presented and we did not yet adjust for potential confounding factors. We shall be cautious when interpreting the results since many factors can influence the immune system. Before

Table 1. Infants' IL-10 blood level and Hib antibody titer at 6 months according to prenatal PCB exposure

Immunological parameter	Low PCB exposure Geometric mean (Confidence interval)	High PCB exposure Geometric mean (Confidence interval)
IL-10 (pg·mL^{-1})	12.0 (8.0 – 18.1) n = 20	1.57 (0.96 – 1.10) n = 26
Hib IgG titer (mg·L^{-1})	12.7 (8.4 – 19.4) n = 16	2.85 (1.63 – 5.01) n = 26

Table 2. Number of infectious episodes during the first year of life according to prenatal PCB exposure

Infection	All infants Number of episodes ± standard error (n = 89)	Low PCB exposure Number of episodes ± standard error (n = 44)	High PCB exposure Number of episodes ± standard error (n = 45)
Colds and URTIs[1]	2.28 ± 0.18	2.18 ± 0.27	2.38 ± 0.24
Otitis	3.15 ± 0.2	3.48 ± 0.31	2.82 ± 0.24
Pneumonia	0.57 ± 0.07	0.39 ± 0.09	0.76 ± 0.12
Bronchiolitis and bronchitis	1.04 ± 0.14	0.8 ± 0.14	1.29 ± 0.23
Gastro-intestinal infections	0.82 ± 0.1	0.68 ± 0.13	0.96 ± 0.14
Tonsillitis	0.2 ± 0.04	0.18 ± 0.06	0.18 ± 0.06

[1] Upper respiratory tract infections

Table 3. One-year risk (incidence proportion) of experiencing frequent infectious episodes according to prenatal PCB exposure

	One-year risk			
Event	Low PCB exposure (n = 44)	High PCB exposure (n = 45)	Relative risk	χ^2 test
Colds and URTIs[1] (3 episodes or more)	0.36	0.47	1.28 (0.78 – 2.12)	0.324
Otitis (5 episodes or more)	0.27	0.2	0.73 (0.34 – 1.56)	0.419
Pneumonia (1 episode or more)	0.34	0.58	1.69 (1.04 – 2.74)	0.025
Bronchiolitis and bronchitis (2 episodes or more)	0.18	0.31	1.71 (0.80 – 3.67)	0.158
Gastro-intestinal infections (2 episodes or more)	0.16	0.27	1.68 (0.73 – 3.86)	0.216
Tonsillitis (1 episode or more)	0.18	0.18	0.98 (0.40 – 2.38)	0.96

[1] Upper respiratory tract infections

speculating on the effects of PCBs on the immune system, one should await the results of a more thorough statistical analysis with careful attention to potential confounders and covariables.

Our hypothesis is that prenatal PCB exposure impairs the development of the immune system. This impairment should be reflected by a weaker production of antibodies following the vaccination (and thus a lower titer in the infants blood). The higher Hib titer in the high PCB-exposure group is puzzling, but this association can be due to many factors. The number of vaccine shots received, the age of the baby, and the period between the last shot and the blood sampling are critical factors to control for before speculating on the significance of this association.

The infants in the high PCB-exposure group tend to experience more infectious episodes in the first year of life compared to the ones in the low PCB-exposure group. It will be interesting to investigate the implication of breast-feeding, vitamin A status and omega-3 levels in this association.

It is too early to draw any conclusions on the effects of PCBs on the immune system. Nevertheless, there seems to be a crude association with prenatal PCB exposure and the incidence of infections. It is not known whether this association is due to the PCB exposure itself or to covariables such as nutrition and lifestyle. Exhaustive statistical analysis (in which many of the potential confounders will be evaluated) will begin in September 2001.

Expected Project Completion Date

Recruitment of pregnant women ended in April 2001. By September 2001, all the infants will be born and they will all be at least one-year old in September 2002. The last trip for the collection of the biological samples and the review the medical charts is planned for October 2002.

The construction of the final database began in March 2001. Data entry should be complete by December 2002. The final data analysis, the writing of the report and of the publications will take place between January 2003 and March 2003. The project will be completed in March 2003.

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Mercury in Salluit: Effects of Mercury on Oxidative Status and Sensorimotor Functions

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Abstract

Among all contaminants present in different aquatic ecosystems in Canada, methylmercury is a major source of concern for public health. Some studies (Grandjean et al. 1994) suggest that methylmercury toxicity can be detected at levels far below the lowest observed adverse effect level proposed by the World Health Organization (10 to15 ppm in maternal hair). Thus, it seems important to determine with precision the minimal dose at which oxidative stress and neurotoxic effects can be identified. The main goal of this project is to investigate the effects of mercury on sensorimotor functions and on markers of oxidative stress in the population of Salluit, Nunavik (northern Quebec). A total of 113 individuals were tested for neuromotor performances and also agreed to give a sample of urine, blood and hair for analysis of mercury and persistent organic pollutants. Results are not available at this time.

Key Project Messages

1. This study aims at studying subtle effects mercury (Hg) can have on brain functions.
2. Measurements done in the blood will tell us more about early signs of Hg toxicity, particularly concerning cardiovascular disease.

Objectives

1. To evaluate the oxidative status of Sallumiut exposed to Hg.
2. To quantify the effects of Hg on sensorimotor functions with highly sensitive measures.

Introduction

In 1998-1999, at the request of the Municipal Council of Salluit, Hg exposure of 140 Salluit, Quebec residents was reassessed. Health Canada had tested residents of this community for Hg in the late 1970s and they were tested again in 1992 during the Santé Québec Health survey. Results showed that hair Hg concentrations decreased from the end of the 1970s to 1999. However, further analysis revealed that only levels measured in 1978 were higher than those measured in 1999. Beluga harvest was particularly abundant in 1977 and returned to normal in 1978. That year (1977) was also exceptional for the harvest of other species such as lake trout and seal. This could explain why high Hg concentrations were found in the blood of residents who provided samples of blood in the spring of 1978. Mercury is mainly present as methylmercury (MeHg) in fish and marine mammals and their consumption constitutes an important source of exposure especially in sustenance population such as the Inuit (Dewailly et al. 2001). Results of a food survey carried out in the community of Salluit in 1979 indicated that the main source of Hg exposure was the consumption of beluga, lake trout and seal liver (Wheatley and Wheatley 1981).

According to recommendations formulated by the World Health Organization, hair Hg concentrations should not exceed 50 ppm in adults and 15 ppm in pregnant women (World Health Organization 1990). The highest concentration noted in 1999 was 30 ppm and no women of childbearing age exhibited concentrations higher than 15 ppm (maximum = 14 ppm).

In order to assess oxidative damage due to MeHg exposure, glutathione peroxidase and glutathione reductase activities were also measured in blood samples and were compared to activities measured in blood of healthy donors from Québec City. Interestingly, data indicated a trend toward higher antioxidant activities in the Sallumiut group. Glutathione determinations were performed as well, but abnormally low values were obtained likely due to glutathione instability during blood processing or shipment.

Methylmercury is a highly toxic environmental neurotoxin that can cause irreparable damage to the central nervous system (Choi 1989, Clarkson 1993, Clarkson 1997). Chronic exposure to MeHg may cause a wide variety of neurological impairments including prickling, paresthesia, impaired peripheral vision, impaired hearing, impaired taste and smell, slurred speech, paraplegia, muscle weakness, irritability, memory loss, depression, sleeping difficulties, cerebella ataxia, and tremors (Agency for Toxic Substances and Disease Registry 1994). Other studies have suggested that low level exposure to MeHg was associated with changes in sensorimotor functions (Beuter and de Geoffroy 1996, Beuter et al. 1999a, 1999b, Rice 1996a, 1996b).

Although the underlying biochemical and molecular mechanisms that lead to impaired cell function and nerve cell degeneration are not well understood, there is abundant evidence supporting the hypothesis that a major mechanism of MeHg neurotoxicity involves an oxidative stress (Sarafian and Verity 1991, Yee and Choi 1996). Mercury increases production of reactive oxygen species via deregulation of mitochondrial electron transport as well as through glutathione depletion (Lund et al. 1993). The oxidative stress hypothesis is clearly supported by the finding that MeHg neurotoxicity can be inhibited by various antioxidants including selenium (Se) (Park et al. 1996) and N-acetyl-L-cysteine, a precursor of glutathione (Ornaghi et al. 1993).

In collaboration with the Municipal Council of Salluit, a new study was set up for 2000-2001 to evaluate the oxidative status of Sallumiut exposed to Hg and to quantify the effects of Hg on sensorimotor functions using highly sensitive measures.

Activities in 2000-2001

Preparation

From April to December 2000, the activities related to this research project centered on the development of protocols for blood sampling and manipulation. Optimal conditions of storage, shipping and processing of collected samples were determined to avoid the degradation of gluthatione. Specific testing conditions were also determined for glutathione peroxidase and glutathione reductase activity measurements in whole blood and plasma. Finally, a field nurse, previously hired and trained, prepared all material needed for sample collection, and worked on the elaboration of the consent form and a questionnaire documenting current health status, lifestyle and past medical history.

Researchers from the Cognitive Neuroscience Centre, Movement Disorders Laboratory, have developed, during the last years, neuromotor tests based on sophisticated technologies (laser, infrared, optical encoder system, CCD sensors, etc.). A Ph.D. student was trained to administer these tests to the Salluit participants. All material needed for neuromotor tests was also prepared and tested. A document was prepared to demonstrate and explain in a simple way the assessment to be administered to participants.

Recruitment

Fieldwork was carried out in Salluit from February 5 to March 31, 2001. A total of 125 Salluit residents signed the consent form and participated in the present study.

Of these, 85 (68%) participants had taken part in the 1999 study on temporal trends; the others (n = 40) were recruited from the Salluit population list.

Three local research assistants were hired and trained to assist the field workers. Their tasks included communication to the local population, translation and assisting the field workers in their respective tasks (blood and hair sampling, administering the questionnaire, conducting neuromotor tests). To recruit participants, the first step was to meet with the local health committee and prepare a radio show to inform the population about the research project and spark their interest. Furthermore, posters informing the population about the study, public meetings and personal invitation letters were also used as recruiting tools.

Collection of data

Data collection was performed in four steps. 1) During the initial meeting between each participant and field workers and their assistants, participants were informed about the objectives of the previous and present research, signed a consent form, provided a hair sample, and were interviewed to fill in the questionnaire. For participants of the 1999 study, individual Hg results in biological samples were presented again and discussed if needed. 2) Participants were then asked to come back the next morning for urine and blood sampling. 3) Participants returned for another appointment for the neuromotor testing measures of tremors, postural sway, simple and multiple reaction time tasks, eye-hand coordination in different pointing tasks, rapid alternating movements and rhythmic hand movements. The total duration of the tests was about 90 minutes. 4) The nurse reviewed medical files to obtain more information on medical history and actual medication.

To insure proper conservation of blood samples during the research project, 25 to 50 kg of dry ice was sent to Salluit once a week. Samples were sent to the Quebec Toxicology Laboratory and to Dr. M.-É. Mirault's laboratory for analysis.

Hg and Se were measured in blood and hair. Blood and hair samples were respectively used to assess short- and long-term exposure to Hg. Blood and hair Hg analyses were performed by cold vapour atomic absorption after nitric acid digestion. Blood Se analysis was carried out by graphite furnace atomic absorption after nitric acid digestion. Because of potential confounding effects on sensorimotor endpoints, PCBs and pesticides were measured in plasma samples using high resolution gas chromatography.

Biochemical assessment of the antioxidant status included glutathione and glutathione peroxidase activity levels in blood, and plasmatic levels of oxidized and reduced coenzyme Q10, vitamin C and glutathione, measured by HPLC-coupled electrochemical detection. The oxidized/reduced CoQ10 ratio will provide a redox index, which is used to assess possible oxidative stress effects associated with Hg exposure. Measurements of urinary F2-isoprostanes, which result from in vivo lipid peroxidation, will provide an additional index of oxidative stress. The formation of F2-isoprostanes is currently recognized as the most sensitive and reliable non-invasive assay of oxidative stress in vivo. Since we found that quantification of F2-isoprostanes by commercially available ELISA kits was not reliable, we are currently setting up measurements of iPGF$_2\alpha$-III and iPGF$_2\alpha$-VI by HPLC/ESI/MS/MS, in collaboration with Dr. P. Borgeat. The lipids and lipoproteins profiles are measured by micro-ultracentrifugation, and the fatty acid profiles by gas chromatography. The cholesterol and apolipoprotein B analyses are performed at the Centre de recherche des maladies lipidiques (CHUL-CHUQ).

Results

The measurements are still being processed; therefore, no results are available at this time. Table 1 shows the number of participants who completed the various tests according to gender.

Table 1. Number of participants according to test completion and gender

	Number of participants at each test				Number of participants that completed all tests
	Hair	Blood	Urine	Neurological	
Men	39	35	35	35	32
Women	84	83	83	81	80
Total	**123**	**118**	**118**	**116**	**112**

Discussion and Conclusions

This project attempted to identify subtle adverse effects induced by MeHg in adults (nervous system and oxidation). Considering the protective effects of essential nutrients against Hg toxicity, the results of this study will help Inuit Health authorities to decide whether or not safety guidelines issued by southern authorities apply to them. In that sense, efforts are also underway to characterize risks of prenatal exposure to Hg in the Inuit population.

Expected Project Completion Date

This research project has been reallocated for year 2001-2002. The main objective for this third year will be to perform supplementary laboratory analysis on blood samples collected during the previous phase. Preliminary results will be presented at the Northern Contaminants Program annual results workshop in September 2001.

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Sociodemographic Factors Influencing Nutrition and Contaminant Exposure in Nunavik

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Abstract

This study examined contaminant and nutrient intake through traditional/country foods among the Inuit population of Nunavik according to various sociodemographic factors. Results showed that the median traditional/country food intake was higher among Inuit 40 years of age and older than among Inuit 18 to 39 years old. Mean age adjusted traditional/country food intake decreased as the level of formal education increased. Inuit living in couples appeared to have a higher level of traditional/country food intake than single, divorced or widowed Inuit. Results also showed that the median contaminant intake increased with age and the geometric mean age adjusted contaminant intake was higher among Inuit receiving less formal education, among those living in couples and among Inuit living in households of six or more persons. For several nutrients, mean age adjusted intake was higher among residents living in Ungava coast communities as compared with residents of Hudson coast communities. Results showed that with an increase in the level of formal education completed by an individual, the more their diet was comprised of some nutrients that are commonly deficient in Inuit diets. Similar nutrient intakes were observed among Inuit living in couples, notably among one-family households. Inuit who did not have a job had a lower mean intake of nutrients as compared to Inuit having one or more jobs. These results may be helpful in identifying which segments of the population (as defined by some traditional sociodemographic variables) are "at risk" for certain contaminant exposures and nutrient deficiencies, as related to traditional/country food consumption. This information will help public health authorities in Nunavik to target and design effective food protection and promotion strategies for the consumption of traditional/country foods for specific groups within the Nunavik population.

Key Project Messages

1. Some sociodemographic characteristics (age, education, employment, marital status, etc.) are similar among Nunavimmiut with a higher level of traditional/country food consumption, higher contaminant

exposures, and more frequently having certain nutritional deficiencies.

2. Differences in contaminant and nutrient intake can be related to such things as availability of and access to certain traditional/country food species and market food items.
3. The identification of the relationships between sociodemographic factors and traditional/country food consumption, nutrient intake and contaminant exposure can be used by public health authorities to identify specific "at risk" groups in Nunavik and better understand the potential factors related to their levels of contaminant exposure and nutritional status.

Objectives

The main objective of this research project was to examine sociodemographic factors affecting contaminant exposure and nutritional status of Inuit in Nunavik. The specific objectives were to:

1. Examine traditional/country food, contaminant and nutrient intake among the Inuit in the context of their socio-economic status and reported status of individual food availability.
2. Examine the relationships among the structure of Inuit households and the intake of traditional/country foods, contaminants and nutrients.
3. Establish the link between contaminant intake, the quantity, quality and source of Inuit food consumed and a number of sociodemographic factors, considering the potential interactive effect of age on some factors.

Introduction

Traditional/country foods are the primary source of Inuit exposure to most persistent environmental contaminants. Over the past decade, various studies and programs in Nunavik have been conducted to reduce contaminant intake while still maintaining nutritional benefits in the diet (e.g. Dewailly et al. 1989, 1991, 1992, 1993, 1994, 1996, Blanchet et al. 2000). To document and protect the dietary benefits of a traditional Inuit diet, while considering the health risks associated with the presence of contaminants in these foods, dietary surveys have been conducted among various Inuit populations to examine the quality and the quantity of traditional/country foods consumed. In most dietary studies, food intakes are only estimated by age and gender and very few studies verify the relationships between other sociodemographic factors and traditional/country food consumption. For health officials to more accurately identify groups within the population potentially "at risk" for contaminant exposure and nutritional deficiencies, and to better understand the potential factors attributed to these diet-related circumstances, a more thorough investigation of the relationships between traditional sociodemographic variables, traditional/country food consumption, and consequent contaminant and nutrient intake is required. This data would then be used to more accurately develop and orient health protection and promotion strategies related to these issues. The Santé Québec Nutrition Survey database is a potential source for this type of information and analysis since food intake and socio-demographic data are readily available and representative of the entire region of Nunavik (Santé Québec 1995).

Activities in 2000-2001

Activities in 2000-2001 consisted of a detailed analysis of the existing data on food intake among the Inuit of Nunavik collected in 1992 during the Santé Québec Health Survey (Santé Québec 1994, 1995) with an extension of our analysis to contaminant intakes by using contaminant databases previously developed at the Public Health Research Unit-CHUL. The target population of the Santé Québec Health Survey was comprised of all permanent residents of private households living within the borders of Nunavik, excluding households consisting of only non-Inuit people and people not related to any Inuit and institutionalized individuals. Food consumption data was obtained using a 24-hour dietary recall administered during the Santé Québec Health Survey. The 24-hour recall was completed by 433 Inuit ranging from 18 to 74 years of age (197 men and 236 women). Accompanied by an Inuit interpreter, nurses went to respondents' homes and conducted dietary interviews to obtain a detailed and precise description of foods consumed in the previous 24 hours (Santé Québec 1995). Food contaminant data was drawn from the database elaborated in 1994-1996 through work conducted for the project Health Risk Assessment and Elaboration of Public Health Advice Concerning Contaminants in Nunavik, supported by the Northern Contaminants Program (Dewailly et al. 1996).

The following contaminants were included in the present study analyses: lead, mercury, p,p'-DDE and PCB as expressed as Aroclor 1254:1260 (1:1). Nutrient data were drawn from the Canadian Nutrient Data File (Health Canada 1991), and the following nutrients were included in this study: energy, protein, lipid, carbohydrate, vitamins A, C and D, carotene, folic acid, dietary fibre, iron, calcium, magnesium, and the sum of eicosapentanoic acid (EPA) and of docosahexanoic acid (DHA). The following sociodemographic variables were obtained from the

Santé Québec database (Santé Québec 1994) were also included in the analyses: sex; age; sector of residence (sector A corresponding to sectors III and IV of the collective agreement and are characterized as communities having greater ease of access to the south, i.e. greater number of regular flights to the regional centre and south, and sector B corresponding to sector V of the collective agreement and being characterized as communities having less ease of access to the south [Collective Agreement 1989-1991]); coastal region (Ungava and Hudson coasts); level of formal education completed; occupation; type of work; number of jobs; marital status; number of persons per household; and structure of households (family or non-family household, multiple family or one-family household, single-parent family or couple). Contaminant intake was calculated by multiplying the daily traditional/country food intake in grams by the corresponding concentration of the contaminant in specific food items. Median intake and geometric mean age adjusted intake of traditional/country foods, nutrients and contaminants were calculated according to sociodemographic variables and the structure of households. For statistical comparisons of medians between categories, the Kruskal-Wallis test was used. Geometric age adjusted means were calculated using analysis of covariance. Statistical analyses were conducted with the Statistical Analysis System (SAS) software and statistical significance was set at = 0.05 (Statistical Analysis System Institute Inc. 1996). The partial non-response, which consists of the non-response on each question or variable, could have resulted in some biased estimates in the present study and thus caution should be used in interpreting the results.

Results

Traditional/country food intake

On the day before the survey, 73% of the Inuit population reported having eaten traditional/country foods. Among the consumers, the median intake of traditional/country foods was 209.0 g. The most popular traditional/country foods consumed during this day were (in decreasing order): caribou, Arctic char, muktuk, seal meat, seal fat and lake whitefish. When estimating the traditional/country food consumption for the Inuit population as a whole, a median intake of 140.0 g was obtained. The median intake of traditional/country foods was significantly higher among Inuit 40 years of age and over than among Inuit between 18 to 39 years of age (Table 1). Mean age adjusted traditional/country food intake did not vary significantly according to sex, sector of residence or coastal region of residence. However, mean intake of traditional/country food among Inuit with a secondary school education was significantly lower than Inuit completing less formal education. Traditional/country food intake did not vary significantly according to individuals' occupation, the type of work they did or the number of jobs they held. However, traditional/country food intake appeared to be related to marital status, with Inuit who were divorced, separated or widowed showing the lowest mean intake of traditional/country foods. Traditional/country food consumption did not vary significantly according to the number of persons per household and the structure of households.

Contaminant intake

As previously mentioned, contaminant intake was based on the traditional/country food intake of Inuit participants the day before the interview (a total of 24 hours) and not on other days. On the day before the survey, the median contaminant intake among Inuit 40 years of age and over was significantly higher than that among Inuit between 18 to 39 years of age (data not shown). The geometric age adjusted mean contaminant intake did not vary significantly according to sex or coastal region of residence. However, mean PCB, p,p'-DDE, mercury and lead intake was higher among Inuit in sector B (those communities having less regular access to the south) than Inuit in sector A (those communities having greater access to the south). With the exception of p,p'-DDE intake, which was not related to the level of education, mean age adjusted PCB, mercury and lead intake was significantly higher among Inuit with a lower level of formal education as compared to Inuit having completed secondary school. The mean contaminant intake did not vary significantly according to occupation, type of work or the number of jobs an individual held. However, mean age adjusted intake of p,p'-DDE and mercury was significantly higher among Inuit who were married or declared having a common-law spouse than among single, divorced or widowed Inuit. Finally, contaminant intake did not vary according to the structure of households (e.g. single parent, family, multiple family).

Nutrient intake

Median intake of carbohydrates, vitamins A and C, carotene, dietary fibre and calcium was significantly lower among Inuit 40 years of age and over than among Inuit between 18 to 39 years (data not shown). In contrast, Inuit aged 40 years and older had a higher median intake of protein, iron and EPA+DHA. Age adjusted geometric mean intake of energy, protein, lipid, carbohydrate, folic acid, iron, calcium and magnesium was significantly higher among men than women. The EPA+DHA intake also appeared higher among men than women. Age adjusted mean intake of energy, protein, lipid, carotene, vitamins

C and D, folic acid, dietary fibre, calcium and magnesium was significantly higher among individuals living in sector A (communities with greater access to the south) than in sector B (communities with less access to the south). Residents in Ungava coast communities had higher mean intake of carbohydrates, vitamin C, folic acid (Table 1), dietary fibre, calcium and magnesium than residents of Hudson coast communities. Among Inuit with a secondary school level of formal education, mean intake of carbohydrate, vitamin A, carotene, dietary fibre, calcium and magnesium was higher than those among Inuit with lower levels of formal education. Inuit who did work showed the highest intake in energy, carbohydrate, vitamin A, carotene, folic acid, dietary fibre, calcium and magnesium, whereas Inuit not currently having a job (including Inuit on unemployment insurance and social welfare) showed the lowest average intake in energy, carbohydrate, carotene, folic acid and dietary fibre. Blue collar workers showed the highest intake of energy and carbohydrate whereas Inuit in the "other" category (including housework, students or Inuit who did not work) had the lowest intake for these nutrients. Professionals and managers had the highest intake of vitamin A whereas blue collar workers had the lowest intake of vitamin A. Mean intake

Table 1. Median* and mean age adjusted intake of Inuit traditional/country foods in Nunavik according to sociodemographic factors**

Sociodemographic	factors	n	Median	*p*	Mean	*p*
Age:	18-39 years	249	104.0	0.0001	—	—
	40-74 years	184	201.4			
Sex:	Men	197	144.5	0.0001	122.0	0.22
	Women	236	116.2		105.4	
Sector of residence:	A (greater access)	243	130.1	0.18	105.8	0.23
	B (lesser access)	190	140.1		122.0	
Coastal region:	Hudson	230	140.0	0.36	117.9	0.41
	Ungava	203	139.7		107.0	
Education:	No schooling	86	188.9	0.0001	129.2	0.04
	Elementary school	93	147.3		134.6	
	Secondary school	184	70.0		90.6	
Occupation:	Work	228	124.0	0.34	102.2	0.54
	Housework	46	149.5		116.4	
	Jobless	52	143.7		129.3	
	Other occupations	34	140.0		122.7	
Type of work:	Professional/Manager	57	140.1	0.13	121.1	0.33
	White collar	95	113.9		96.5	
	Blue collar	55	122.5		103.0	
	Other occupations	154	151.0		126.4	
Number of jobs:	None	110	147.6	0.08	127.2	0.35
	1 job	205	140.0		105.6	
	2 jobs or more	46	81.4		98.0	
Marital status:	Married/common law spouse	226	153.2	0.01	121.3	0.05
	Separated or widowed	36	76.2		80.1	
	Never married (single)	101	92.7		98.0	
Number of persons per household:	1-3 persons	51	125.2	0.07	101.2	0.15
	4-5 persons	74	109.4		104.9	
	6 persons or over	95	151.1		141.0	
Private households:	Family households	415	140.0	0.95	113.0	0.78
	Non-family households	18	140.0		104.2	
Family households:	Multiple family	153	140.0	0.53	115.5	0.76
	One family	262	140.0		111.0	
One-family households:	Couple	223	140.0	0.35	111.2	0.35
	Single-parent family	39	136.0		90.9	

* Median intake in grams and p value obtained by Kruskal-Wallis test

** Geometric mean adjusted for age and *p* value obtained by covariance analysis of carotene and vitamin C appeared to be higher among professionals and white collar employees ($p = 0.07$), whereas lower intake for these nutrients was observed among blue collar workers and Inuit in the "other" category. Mean folic acid intake was also higher among professionals and managers. Inuit who did not have a job had the lowest intake of energy, lipid, carbohydrate, vitamin A, folic acid, dietary fibre, calcium and magnesium as compared to Inuit having one or more jobs. Inuit who were married or had a common law spouse had the highest intake of energy, protein, lipid, vitamins A and D, folic acid, dietary fibre, iron, calcium and magnesium whereas divorced/ separated or widowed Inuit had the lowest intake of these elements, with the exception of calcium intake which was significantly lower among single Inuit.

The nutrient intake varied little according to the number of persons per household with the exception of mean carbohydrate intake which was significantly higher in Inuit households of one to three persons as compared to households of 6 persons or more. Age adjusted mean intake of nutrients did not vary significantly according to the type of private households. However, mean intake of energy, protein, lipid ($p = 0.06$), vitamin A, carotene, folic acid, dietary fibre and magnesium was significantly higher in one-family households than in multiple-family households. Inuit living as couples had the highest mean intake of energy, protein, lipid, iron and magnesium as compared with single-parent Inuit. Vitamin D and calcium intake also appeared to be higher ($p = 0.06$) among Inuit living as couples compared with single parent Inuit.

Comparison of nutrient intake with recommended nutrient intake

Median intake of protein, vitamins A and C, folic acid, iron, calcium and magnesium were compared with daily recommended nutrient intake (RNI) levels based on Health Canada's nutrition recommendations (Health Canada 1990). Protein intake exceeded the RNI regardless of sociodemographic factors. In contrast, vitamin A intake fell below the RNI for all sociodemographic variables. Similarly, vitamin C and folic acid intake also did not meet the RNI for any sociodemographic variables. With respect to minerals, median iron intake appeared to meet the RNI regardless of the sociodemographic factor while calcium and magnesium intake was deemed insufficient (did not meet RNI) for Inuit in all categories.

Food availability

Among the Inuit who answered the question concerning the lack of food in their house during the month prior to the survey (n = 210), 24% declared that they were lacking food or did not have enough to eat during this period. However, the comparisons presented here should be approached with caution due to the small sample sizes in each category. The reporting of a lack of food did not vary according to sex, age or sector of residence. However, a greater proportion of Inuit living in Hudson coast communities reported having lacked food as compared with Inuit residing in Ungava coast communities. The lack of food did not vary according to the reported level of education. A greater proportion of Inuit who declared housework as their occupation appeared to have lacked food in the month prior to the survey. This lack of food was not related to the type of work but Inuit who reported having no job during the year before the survey more frequently declared having lacked food the previous month as compared to Inuit who had one or more jobs. The lack of food did not vary according to the number of people living in a household, however a greater proportion of separated, divorced or widowed Inuit stated having lacked food during the month prior to the survey. Further, this lack of food did not vary according to the structure of households. When verifying nutrient intake, taking into consideration food availability, the median intake of protein, carbohydrate, carotene, vitamin C, folic acid, dietary fibre and magnesium appeared to be lower among Inuit lacking food as compared with Inuit who had enough food in the month prior to the survey; this difference was only statistically significant for dietary fibre and magnesium. Contaminant intake did not vary significantly according to the reported availability of food.

Discussion

This study has identified some sociodemographic factors which may influence Inuit traditional/country food consumption. Traditional/country foods are the primary source of exposure to environmental contaminants for Inuit and also provide several nutrients to the Inuit diet. Therefore, the sociodemographic factors identified in this study also may indirectly influence individual contaminant exposure and nutrient intake. In this study, we used a 24-hour dietary recall to verify the statistical relationships between traditional/country food, contaminant and nutrient intake, and sociodemographic factors. The value of the 24-hour dietary recall method in assessing the intake of groups is well established (Willett 1998). It can provide a fair estimate of a population's average intake. However, 24-hour dietary recalls are rarely representative of long-term intake and do not allow the identification of the proportion of individuals "at risk" for contaminant exposure and nutrient deficiencies. Hence, results obtained here do not permit us to infer a cause-effect relationship between sociodemographic factors and contaminant exposure or nutrient deficiencies.

The present study shows that although traditional/country foods are of the utmost importance for Inuit, more traditional/country foods were consumed by older than younger Inuit adults. Results from the Santé Québec survey (1995) indicated that traditional/country foods contributed more to the Inuit diet among older aged individuals than among younger Inuit, whereas market foods contributed more to the diet of younger Inuit. Kuhnlein (1994) made similar observations among Baffin Inuit women and Dene/Metis women. In the Keewatin Health Survey, Moffat and Young (1994) found that food consumption patterns were changing among the Inuit population in that region. Although most Inuit of the Keewatin region consumed considerable amounts of traditional/country foods, young people appeared to depend more heavily on market foods. Among Inuit of Aklavik, Northwest Territories, Wein and Freeman (1992) reported that children liked traditional/country foods just as much as adults, however, children rated most market foods higher in preference than adults, likely reflecting the greater availability of market foods in recent years.

Our results show that on the day prior to the survey, no geographical differences in traditional/country food consumption existed in Nunavik. However, data from the food frequency questionnaire revealed that daily traditional/country food intake of Inuit women, on an annual basis, was significantly higher among women residing in Hudson coast communities as compared with women living in Ungava coast communities. Results of Santé Québec survey (1995) also revealed that residents along the Hudson coast seem to depend more on traditional/country foods than on market foods. Hence, we can conclude that traditional/country food consumption (on an annual basis) may be higher among residents in Hudson coast than in Ungava coast communities. This reflects the fact that Ungava coast communities (especially in Kuujjuaq which is the administrative capital of Nunavik) are better supplied in market foods than their Hudson coast neighbours, probably because this area was exposed earlier and more rapidly to southern Quebec influence. Similar differences in traditional/country food consumption according to the degree of urbanization of Inuit communities is reported by others (Schaefer and Steckle 1980, Kuhnlein 1992, Wein 1995, Egeland et al. 1998, Pars et al. 2001). According to Kuhnlein (1992), the use of traditional/country foods in the North depends on the remoteness of the community from urban centres among other things. The variation in traditional food consumption according to region may be also attributed to the territorial availability of wildlife species. Effectively, the variation in abundance and availability of different species regionally, seasonally, and from year to year are natural sources of variation in traditional/country food consumption (Van Oostdam et al. 1999).

Freeman et al. (1992) found that the level of formal education was negatively related to the consumption of traditional/country foods. It was suggested that increased formal education and employment by Inuit can limit, but not necessarily eliminate, involvement in harvesting activities and therefore consumption of traditional/country foods (Van Oostdam et al. 1999). In our study, the mean age adjusted traditional/country food intake was significantly lower among Inuit reporting a higher level of formal education. Wage employment and household income also appear to have an influence on traditional/country food consumption (Chabot 1998, Rasmussen 1998, Lawn et al. 1998, Kuhnlein 1995). However, our results did not show significant differences in traditional/country food intake for variables relating to working status and occupation. Moreover, the traditional/country food consumption was not analyzed according to the income in this study since 52% of Inuit respondents did not answer the question measuring income in the Santé Quebec survey. Thus we can not reject the possibility that traditional/country food consumption may be related to individual income among Nunavimmiut.

Traditional/country food consumption did appear to be related to marital status in this study. The analyses showed that Inuit living in couples were more likely to consume traditional/country foods, possibly suggesting that single, separated or widowed Inuit may have less access to traditional food resources or the resources to attain these foods (equipment, etc.). Recently, Duhaime et al. (2001) reported that the presence of a male as the head of a household and, to a lesser extent, access to a wage income raised the proportion of traditional/country foods in the total diet among Nunavik women. Wein et al. (1991, 1988) also reported that the availability of traditional/country foods depended greatly upon having a hunter in the family who was equipped with adequate resources (including means of transportation) and skills. A recent study conducted among Nunavik women of childbearing age revealed that frequent fish eaters were likely to be less educated, to share their house with more adults, and to live in more crowded conditions (Muckle et al. 2001). The authors attributed these associations to the fact that fish, which is usually caught by a family member and is available at no cost in a community freezer, is less expensive than many market foods. Our study did not reveal significant differences for traditional/country food consumption according to the structure of Inuit households. It is possible that the low number of individuals in some categories may have hidden these relationships or they simply did not exist among this data set. However, it appeared that more male respondents than female respondents lived as a couple and, among single-parent families, 80% of women were at the head of the family.

This study permitted the examination of contaminants intake according to various sociodemographic factors among the Inuit population of Nunavik. However, as mentioned above, results do not permit us to establish causal relationships even though significant statistical associations were observed between the study variables. The combined results from several studies are needed to support causal relationships between such factors as sociodemographic elements and contaminant exposures. In this study, the main differences in contaminant intake observed according to sociodemographic factors can be explained by the quantity and items of traditional/country food consumed on the day before the survey. These factors depend on the availability and accessibility of traditional/country foods at this time, and the concentration of contaminants in specific traditional/country food items, which vary greatly between species. Hence, our results showed that contaminant intake was higher among older Inuit, probably reflecting their higher level of traditional/country food consumption when compared to younger individuals.

Results also showed that contaminant intake was higher among Inuit living in more isolated villages (referred to as sector B by Santé Québec (1994)) than in villages with greater ease of access to the south or the regional centre (referred to as sector A in Santé Québec (1994)), even though traditional/country food intake did not vary significantly according to sectors of residence. This difference may be explained by the source of contaminants consumed. Additional analyses showed that on the day before the survey, Inuit living in sector B communities had eaten a greater amount of marine mammal meat and blubber, which generally contain higher concentrations of contaminants than terrestrial meat or fish, than Inuit living in sector A communities. Our results showed that the daily mean intake of PCB, mercury and lead was higher among Inuit with a lower level of formal education, probably reflecting their higher overall consumption of traditional/country foods. Additionally, Inuit who reported having no formal education appeared to consume more caribou previous to the survey whereas Inuit with an elementary level education appeared to consume more fish. Inuit living in couples showed higher p,p'-DDE and mercury intake than divorced/separated, widowed or single Inuit. This may be explained by a higher marine mammal intake among these individuals. While total traditional/country food intake did not vary significantly according to the number of persons per household, the mean intake of PCB, p,p'-DDE and lead was significantly higher in households of 6 persons or more. This relationship can be explained by further analyses conducted in this study which showed that the consumption of marine mammals among Inuit living in households of 6 persons or more was higher than in households with fewer individuals.

Differences in nutrient intake according to sociodemographic factors observed here may be explained by such things as the high price and the lack of availability of some food items (such as fruits and vegetables), the low income of some Inuit households, the general decrease in traditional/country food consumption among some segments of the population and the lack of general nutritional education in the population. Additionally, fear of contaminants may play a role in Inuit food choice behaviour (Dewailly et al. 1994); the potential influence of this information on individual choice is currently being studied (Furgal et al. 2001, Kuhnlein 2001). Moreover, our results on food availability show that a greater proportion of Inuit in Hudson coast communities, jobless Inuit and separated/divorced or widowed Inuit declared having lacked food in their house during the month prior to the survey. Lawn et al. (1998) indicated that the affordability of the Inuit diet is dependent on many factors including food prices, income, consumer choices and food availability. For 1993, the cost of food for a family of four represented as much as 83% and 90% of after-shelter family incomes in Kuujjuaq and Salluit, respectively (Lawn and Langner 1994a). In the smaller, most northern Nunavik communities, food prices are higher and there are fewer people with full-time wage employment (Hodgins 1997). Hence, it follows that food security is a serious problem for some families, especially those on social assistance and those with a low family income (Lawn and Langner 1994b). Lawn and Langner (1994b) indicated that substitution of traditional/country foods by market foods such as prepared food items, is easier (less labour intensive), since market foods require less preparation, while Morrison et al. (1995) reported on the poor nutrient quality of many market food items consumed among some northern populations. Hence, the substitution of traditional/country foods, which are excellent sources of several key nutrients, by market foods is not always desirable, especially when the lower nutritional value of some market food substitutes are considered. We can argue that there is a need to educate Inuit populations about wise market food choices. However, despite the fact that higher nutrient intake has been observed among some sociodemographic Inuit groups, intake of vitamins A and C, folic acid, calcium and magnesium was insufficient for all sociodemographic groups in this study when compared with the recommended nutrient intakes for Canada. These findings are consistent with other studies conducted among Inuit populations (Kuhnlein et al. 1996, Lawn and Langner 1994a, Nobmann et al. 1992, Wein 1986). These nutritional deficiencies could be associated with insufficient consumption of dairy products, fruits, vegetables and whole-grain cereal products and also with a decrease in traditional/country food consumption. In the past, Inuit appear to have succeeded in avoiding nutritional deficiencies by eating all animal parts as well as several plant species and berries. Morrison et al. (1995) indicates that in a transition towards the use of more market foods in northern contemporary diets, the nutritional value of diets has declined because less animal foods are being consumed and vitamin and mineral intakes are not being augmented by frequent consumption of vegetables, fruits and dairy products. We believe this argument to be applicable to our observations in Nunavik.

Conclusions

This study shows that sociodemographic factors such as age, sector of residence, level of education, work occupation, marital status and the household structure (especially in the case of nutrients) may be related to traditional/country food, contaminant and nutrient intake among the Inuit population of Nunavik. It is expected that the results of the present study will help public health authorities in Nunavik, such as the Nunavik Nutrition and Health Committee and the Nunavik Regional Board of Health and Social Services, to target subgroups of the population more likely to be exposed to environmental contaminants or nutritional deficiencies, in order to design more effective food protection and promotion strategies dealing with Inuit traditional/country food consumption.

The promotion of safe food habits among the Inuit population presents several challenges. First, traditional/country food consumption must be maintained or increased because it has given Inuit several advantages such as social well-being, cultural identity, economic value and food security. Moreover, the consumption of marine traditional/country foods, which are rich in n-3 polyunsaturated fatty acids, is believed to protect Inuit against cardiovascular diseases, a major cause of mortality in industrialized countries. The n-3 fatty acids are also increasingly recognized as having a beneficial effect upon visual acuity and contributing to increased birth weight. Similarly, the elevated selenium content in muktuk may reduce the potential risk of mercury poisoning among consumers. Second, according to our results, the distribution and access to local traditional/country food supplies could require attention, particularly among some specific groups of individuals such as separated/divorced or widowed Inuit, which appeared to eat less traditional/country food, to lack food in their household at certain times of the year and to have very low intake of some important nutrients. Third, the consumption of healthy market foods, particularly good sources of vitamin A and C, folic acid, calcium and magnesium, should be promoted. Obtaining these foods would be easier if some market foods are made more available and accessible and promoted through effective nutritional education programs. Finally, the control of the quality of traditional/country foods with respect to contaminant levels should be maintained through regular monitoring, and public health dietary recommendations aimed at reducing exposure to these chemicals should ensure that major nutritional, social and cultural benefits related to traditional/country foods are maintained.

Project Completion Date

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Spatial and Temporal Trends of PCB, PCDD and PCDF Concentrations in Human Milk from Arctic Canada

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Abstract

Organochlorines are persistent food chain contaminants to which the Inuit of Nunavik (northern Quebec) are exposed through their traditional diet. The first objective of this study was to determine the current breast milk concentrations of dioxin-like polychlorinated biphenyls, polychlordibenzo-*p*-dioxins and polychlorodibenzofurans in this population, and compare these data with those obtained in a breast-milk survey carried out in 1990. Our results show a statistically significant 75% decrease in concentrations of dioxin-like compounds in breast milk during the last decade. This decline is consistent with results from other studies carried out worldwide, but seems to be of greater magnitude, and occurred despite the high deposition rates of dioxins and furans predicted in northern latitudes by long-range atmospheric transport models. The current levels of dioxin-like compounds found in breast milk from Nunavik women are now similar to those found in populations exposed to background levels in southern latitudes.

Key Project Messages

1. The breast milk concentrations of dioxin-like compounds in Inuit women of Nunavik have greatly decreased during the last decade.
2. The deposition of polychlorodibenzo-*p*-dioxins and polychlorodibenzofurans in Arctic Canada suggested by a recent modeling study is not reflected by the body burden of dioxin-like compounds in Inuit women of child-bearing age residing in Nunavik.

Objectives

1. To evaluate the current concentrations of polychlorodibenzo-*p*-dioxins, polychlorodibenzofurans and dioxin-like polychlorinated biphenyls in breast milk samples from Nunavik women (2000 study group).
2. To compare these concentrations to those obtained in 1990 in the same region in order to derive a temporal trend.

Introduction

Polychlorinated biphenyls (PCBs), polychlorodibenzo-*p*-dioxins (PCDDs) and polychlorodibenzofurans (PCDFs) are ubiquitous environmental pollutants. These compounds are lipophilic, resist biodegradation and show a strong propensity to bioaccumulate and biomagnify in food chains. Long-range atmospheric transport modelling studies have suggested that they are carried away from their southern sources of emission and deposited in northern latitudes where they accumulate in Arctic ecosystems (Commoner et al. 2000, MacDonald et al. 2000). Data from laboratory animals and human populations accidentally exposed to dioxin-like compounds (DLCs, including PCDDs/PCDFs and non-*ortho*- and mono-*ortho*-substituted PCBs) indicate that these compounds can induce several toxic effects (Hansen 1998, Longnecker et al. 1997, Mukerjee 1998, Safe 1994). Hence, environmental exposure to these toxicants represents a potential health threat. The Inuit population of Nunavik (northern Quebec) is exposed to these compounds through the consumption of sea mammal fat as part of their traditional diet. A recent PCDD/PCDFs continental scale modelling study showed a linkage between U.S. sources of these compounds and their deposition to northern latitudes. The study also drew conclusions relative to human health implications and called for remedial action to protect the Inuit residing in the Canadian Arctic from the health hazard of airborne DLCs (Commoner et al. 2000). Earlier studies have compared the exposure of the populations of Nunavik and southern Quebec to DLCs. A breast-milk survey was carried out between 1989 and 1991 and showed that concentrations of organochlorines (OCs) were three- to seven-fold higher in Nunavik than in southern Quebec (Dewailly et al. 1994, Dewailly et al. 1993b, Dewailly et al. 1992, Dewailly et al. 1989). Another study carried out in 1992 on pooled blood samples from Inuit adults and Caucasians from southern Quebec showed a seven-fold difference between plasma concentrations of DLCs (Ayotte et al. 1997). However, recent data on the body burden of DLCs in the Inuit population of Nunavik are not available. Therefore, it was agreed by the Northern Contaminants Program management committee that the current concentrations of PCDD/PCDFs and coplanar PCBs in breast milk obtained from Nunavik women during 1996-2000 were to be determined in order to derive a temporal trend.

Activities in 2000-2001

Forty-seven breast milk samples were provided by Nunavik women between 1996 and 2000 in the framework of an ongoing neurodevelopment study, and were analyzed for coplanar PCBs, PCDDs and PCDFs. All samples were sent to Axys Analytical Services Ltd (Sidney, B.C.) for OC analyses. Milk samples were spiked with ^{13}C-labelled surrogate standards and were liquid-liquid extracted. Extracts were subjected to a series of chromatographic cleanup steps, resulting in two fractions. One fraction was analyzed for PCDDs, PCDFs and non-*ortho* substituted PCBs and the other fraction was analyzed for mono-*ortho* substituted PCBs. Organochlorine determinations were performed by high-resolution gas chromatography with high-resolution mass spectrometric analysis. Organochlorine concentrations in breast milk were expressed on a lipid basis (lipids measured gravimetrically) and concentrations were converted to dioxin toxic equivalent (TEQ) concentrations using the latest set of international (World Health Organization) toxic equivalency factors (TEFs) (Van den Berg et al. 1998).

Data obtained in 1996-2000 were compared with those obtained in a breast-milk survey carried out in the same region between 1989 and 1991. In the latter study, OC determinations were carried out according to a similar protocol, albeit in a different laboratory (Midwest Research Institute, Kansas City, KS, USA). DLCs concentrations obtained in 1989 to 1991 were re-converted to TEQs according to the latest TEFs.

Results

Breast milk samples were obtained from 47 Inuit women living in three villages on the East Coast of Hudson Bay between 1996 and 2000 (2000 study group). The average maternal age in this group was 25 years (95% CI: 23.4 to 26.7.) and 21% of these women were primiparous. Means and confidence intervals for DLCs concentrations in breast milk are presented in Table 1. One sample was excluded from the analyses because of its abnormally low lipid content. Mean total TEQ concentration found in breast milk in 1996 to 2000 (17 ng·kg^{-1} lipids) is mostly attributable to PCBs (62%), in particular to the mono-*ortho* congeners (40%). PCDDs account for 27% of total TEQs and PCDFs for the remaining 11%.

The data obtained for the 2000 study group were compared with those obtained in a previous study addressing breast-milk contaminants in Nunavik between 1989 and1991

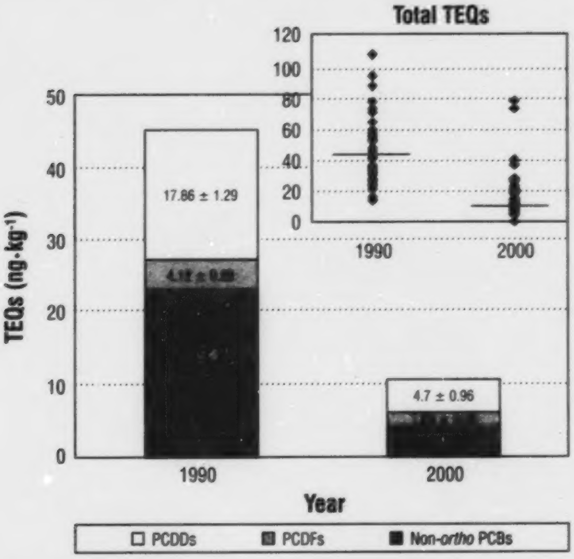
Table 1. Concentrations of PCDDs, PCDFs, non-*ortho* and mono-*ortho* PCBs in breast milk from 46 Inuit women, Nunavik, 1996-2000

Congener	IUPAC #	% detected	Mean	[CI 95%]	TEF	Mean TEQ	[CI95%]
Non-*ortho* PCBs			ng·kg^{-1} lipid (ppt)			ng·kg^{-1} lipid	
3,3,4,4'-CB	(77)	93%	18.17	[8.91 – 27.43]	0.0001	0.002	[0.001 – 0.003]
3,4,4',5,-CB	(81)	76%	5.64	[1.37 – 9.90]	0.0001	0.001	[0.000 – 0.001]
3,3',4,4',5-CB	(126)	91%	34.63	[24.30 – 44.97]	0.1	3.463	[2.430 – 4.497]
3,3',4,4',5,5'-CB	(169)	91%	38.73	[29.52 – 43.95]	0.01	0.367	[0.295 – 0.439]
Total TEQs non-*ortho* PCBs						**3.500**	**[2.472 – 4.528]**
Mono-*ortho* PCBs			μg·kg^{-1} lipid (ppb)			ng·kg^{-1} lipid	
2,3,3',4,4'-CB	(105)	100%	5.75	[4.34 – 7.17]	0.0001	0.575	[0.434 – 0.717]
2,3,4,4',5-CB	(114)	98%	1.06	[0.81 – 1.30]	0.0005	0.529	[0.408 – 0.650]
2,3',4,4',5-CB	(118)	100%	18.83	[13.39 – 24.26]	0.0001	1.883	[1.339 – 2.426]
2',3,4,4',5-CB	(123)	98%	0.16	[0.11 – 0.22]	0.0001	0.017	[0.011 – 0.022]
2,3,3',4,4',5/5'-CB	(156/7)	100%	7.02	[5.23 – 8.81]	0.0005	3.509	[2.615 – 4.404]
2,3',4,4',5,5'-CB	(167)	100%	1.36	[1.01– 1.71]	0.00001	0.014	[0.010 – 0.018]
2,3,3',4,4',5,5'-CB	(189)	96%	0.60	[0.46 – 0.73]	0.0001	0.060	[0.046 – 0.073]
TEQs (mono-*ortho* PCBs)						**6.572**	**[4.950 – 8.194]**
TEQs (PCBs)						**10.072**	**[7.540 – 12.596]**
Dioxin congeners			ng·kg^{-1} lipid (ppt)			ng·kg^{-1} lipid	
2,3,7,8-TeCDD		30%	2.20	[1.39 – 3.01]	1	2.200	[1.388 – 3.012]
1,2,3,7,8-PeCDD		59%	4.62	[2.12 – 7.11]	1	4.617	[2.123 – 7.111]
1,2,3,4,7,8-HxCDD		35%	3.39	[0.13 – 6.66]	0.1	0.339	[0.013 – 0.666]
1,2,3,6,7,8-HxCDD		78%	12.87	[9.86 – 15.88]	0.1	1.287	[0.986 – 1.588]
1,2,3,7,8,9-HxCDD		50%	2.24	[1.69 – 2.79]	0.1	0.224	[0.169 – 0.279]
1,2,3,4,6,7,8-HpCDD		89%	9.09	[8.09 – 11.08]	0.01	0.091	[0.081 – 0.101]
OctaCDD		100%	58.39	[49.01 – 67.77]	0.0001	0.006	[0.005 – 0.008]
TEQs (dioxins)						**4.704**	**[2.765 – 6.642]**
Furan congeners			ng·kg^{-1} lipid (ppt)			ng·kg^{-1} lipid	
2,3,7,8-TeCDF		39%	2.17	[1.30 – 3.05]	0.1	0.217	[0.130 – 0.305]
1,2,3,7,8-PeCDF		(n = 1)	22.00		0.05	1.100	
2,3,4,7,8-PeCDF		48%	4.91	[2.33 – 7.50]	0.5	2.457	[1.164 – 3.749]
1,2,3,4,7,8-HxCDF		59%	3.41	[1.20 – 5.63]	0.1	0.341	[0.120 – 0.563]
1,2,3,6,7,8-HxCDF		35%	3.32	[-0.26 – 6.91]	0.1	0.332	[-0.026 – 0.691]
1,2,3,7,8,9-HxCDF		9%	7.86	[-7.22 – 22.94]	0.1	0.786	[-0.722 – 2.294]
1,2,3,4,6,7,8-HpCDF		37%	4.76	[0.91 – 6.61]	0.01	0.038	[0.009 – 0.066]
OctaCDF		13%	10.52	[-7.23 – 28.26]	0.0001	0.001	[-0.001 – 0.003]
TEQs (furans)						**1.884**	**[0.608 – 3.160]**
Total TEQs (all DLCs)						**17.12**	**[12.43 – 21.80]**

(1990 study group). The 1990 study group comprised 40 Inuit women recruited in 14 villages of Nunavik; 80.5% lived in the Hudson Bay area, 13.8% lived in the Hudson Straight area and the remaining 5.7% lived in the Ungava Bay area. The mean maternal age of the 1990 study group was 26 years (95% CI: 24.5 to 27.9), which did not differ significantly from the mean maternal age of the 2000 study group. Information on parity was unavailable, but 33% of these women had never breast-fed before, suggesting that the proportion of primiparous women was equal to or lower than 33% (Dewailly et al. 1993b).

Figure 1 illustrates the temporal trend observed in breast milk TEQs found in samples collected in Nunavik at both time periods. This comparison is limited to PCDDs, PCDFs and non-*ortho* PCBs since mono-*ortho* PCBs were not measured in the 1990 survey. A 4.5-fold, statistically significant decrease in total TEQs was noted from 1990 to 2000 (see insert in Figure 1). Total non-*ortho*-PCB-related TEQs decreased by a factor of six during this period. Total PCDDs-related TEQs show a 3.8-fold decrease, while total PCDF-related TEQs decreased by a factor of two. In 1990, PCDDs/PCDFs accounted for a slightly lower proportion of total TEQs than non-*ortho* substituted PCBs (49% vs. 51%) but these proportions changed in the 2000 group, and PCDDs/PCDFs became more important TEQs contributors than non-*ortho* PCBs (63% vs. 37%). However, the proportions shown in Figure 1 do not include mono-*ortho* substituted PCBs, which account for a large proportion of TEQs found in breast milk in 2000 (Table 1). When mono-*ortho* PCBs are accounted for, total PCBs account for the larger proportion of total TEQs found in breast milk.

Figure 1. Comparison of TEQ concentrations in breast milk collected in Nunavik in 1990 and 2000



Discussion

This study aimed to assess the current breast milk concentrations of PCDDs, PCDFs and dioxin-like PCBs in Inuit women of child-bearing age residing in Nunavik and compare them to concentrations in samples collected in 1990, in order to identify temporal trends. Our results show that PCBs (non-*ortho* and mono-*ortho* congeners) are the major contributors to total TEQs, followed by PCDDs and PCDFs, an observation previously reported in the Nunavik population (Ayotte et al. 1997). However, a striking 4.5-fold decrease in concentrations of DLCs in breast milk (not including mono-*ortho* PCBs) occurred during the last decade.

Both study-groups were comparable with regard to maternal age, but the area of residence of the participants differed slightly. All participants in the 2000 study group were residents of villages on the East Coast of Hudson Bay, whereas 20% of the 1990 study group resided in the Hudson-Straight area or the Ungava Bay area. However, this is unlikely to affect the results and conclusions drawn in this study. People residing in the Ungava Bay area are less exposed to OCs than on the east coast of Hudson Bay, but this difference is not statistically significant for DLCs (Dewailly et al. 1993a, Dewailly et al. 1993b).

According to a recent review of time trends of OCs found in breast milk, international data indicate a global decline in concentrations of DLCs for several industrialized countries over the last 30 years (LaKind et al. 2001). This decline is clearly observed in several European countries as well as in Japan and Vietnam, but results remain more or less ambiguous for United States and Canada. In most cases, this trend is more pronounced from the 1970s to the mid-1980s and seems to reach a plateau in the early to mid-1990s. According to LaKind et al. (2001), the most compelling evidence of this decline is brought by data collected in Germany showing a 60% decrease in PCDDs and PCDFs breast milk concentrations from 1989 to 1996, a similar trend to that observed in the present study. The results reported here are therefore consistent with the decline observed in PCDDs and PCDFs concentrations in breast milk collected worldwide and, more specifically, they are consistent with data collected in Germany for the same time period.

Our data show that the high deposition rates of PCDDs and PCDFs in Arctic Canada predicted by a recent modelling study (Commoner et al. 2000) are not reflected in the body burden of DLCs compounds in the Inuit women of child-bearing age residing in Nunavik. The current breast milk concentrations of DLCs in this population are now comparable to concentrations reported in the general population of Quebec in 1992 (Dewailly et al. 1992) and in several other populations exposed to background levels of dioxin-like OCs (LaKind et al. 2001). This decline in breast milk concentrations of DLCs may be attributable to decreasing concentrations of these compounds in Arctic biota, to a decrease in the consumption of sea mammal fat in the Nunavik population or to a combination of these factors, and further studies are needed to address these issues.

Conclusion

In summary, breast milk concentrations of all DLCs have greatly decreased in the last decade in samples collected in Nunavik. Therefore, the high deposition rates of PCDD/PCDFs in northern latitudes suggested by a recent modelling study is not reflected by the actual body burden of Inuit women of child-bearing age residing in Nunavik, and levels of DLCs in breast milk collected from these women are now close to concentrations observed in other populations exposed to background levels of DLCs. Other compounds such as polybrominated diphenyl ethers should be given more attention in future breast milk surveys to be conducted in the Canadian Arctic, in view of the rising concentrations of these compounds reported in other populations and their similar toxic properties to other OCs (Darnerud et al. 2001, de Boer and Denneman 1998, Hooper and McDonald 2000, Meironyte et al. 1999, Noren and Meironyte 2000).

Project Completion Date

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Decision Making and Diet in the North: Balancing the Physical, Economic and Social Components

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Abstract

This project addressed two gaps in our understanding of how to effectively manage traditional/country food and contaminant issues in the North: the lack of understanding of how best to include social and cultural benefits and risks associated with traditional/country foods in decision-making processes; and the lack of understanding of the determinants of food choice. This project identified and reviewed potential social and cultural benefits and risks associated with traditional/country foods and food-related activities in the North. A process and the need for their consideration and inclusion in risk management concerning human health and contaminants were then outlined. Over the 2 years of this project, a culturally specific questionnaire was developed, tested and applied to 251 Inuit residents of Kuujjuaq to provide a quantitative assessment of determinants of food choice. Results indicate that perceived behavioural control (i.e. how easy or difficult a person perceives adopting a behaviour) is the strongest predictor of intention to eat traditional/country food three times a week or more, while personal normative belief (i.e. personal feeling of obligation to adopt the behaviour), followed by emotion (i.e. personal feelings associated with the behaviour) and perceived behavioural control are the best predictors of intention to eat store-bought food every day. This is the first quantitative data on this topic in the North to date. Both the development of processes to include cultural and social benefits and risks in decision-making activities, and the identification of the determinants of food choice in Kuujjuaq, increase our understanding of how to effectively make decisions and implement intervention and education programs related to traditional/country foods and contaminants in the Canadian North.

Key Project Messages

1. The collection, consumption, distribution and preparation of traditional/country foods are reported

to define, maintain, express and increase aspects of social, cultural and spiritual well-being in the North.

2. Information on the specific social and cultural benefits associated with traditional/country foods must be collected and made available for consideration in decision-making processes on health and contaminants.
3. Knowledge of contaminants was not found to be a major determinant of the intention to eat traditional/country food. How easy or difficult a person thought eating traditional/country food three times a week or more would be, was the strongest determinant in intention to eat traditional/country food. Feelings, either like or dislike, for the daily consumption of store-bought food, personal belief in this behaviour and the perceived ease or difficulty of adopting it daily were the major influences on an individual's intent to consume store-bought food.
4. The determinants identified in the course of this study explain approximately half of the variance in intent to eat traditional/country food and more than half of the variance in intent to eat store-bought food.

Objectives

1. To develop a conceptual framework for decision making, and strategies for the inclusion of the physical, economic and social/cultural benefits and risks associated with traditional/country food consumption in the North.
2. To develop and apply a survey tool to increase our understanding of the determinants of food choice behaviour in northern communities.

Introduction

While Western science has recently recognized the biological and economic benefits and risks related to traditional/country food, traditional knowledge has long since recognized the many benefits related to these foods in terms of their contribution to physical, social, and spiritual well-being (Borré 1991, Borré 1994, Egede 1995). In some cases, there have been reports of the loss or disruption of these social and cultural components due to confusion and concern over food safety resulting from reports of environmental contamination (Santé Québec 1992, Wheatley and Wheatley 1981, Wenzel 1986). In the face of the threats imposed by environmental contamination in the Arctic, northern health professionals, government representatives and advisory bodies have had the responsibility of "managing," protecting and promoting public health and its relationship to the environment through the balancing of available information, the provision of advice to the public and, in some cases, intervention activities. This has proven to be a difficult, and at times, contentious exercise, in particular because such things as the needs, expectations and preferences of the population have not always been well understood and considered. Little work to date has focused on investigating methods through which to include the consideration for, and balancing of, social and cultural components related to traditional/country food in decision-making processes. Similarly, little attention has been given to gaining a better understanding of the determinants of food choice behaviour in the North and their potential impacts on advisory reception and adherence. Those responsible for the protection and promotion of public health in the North must consider and have access to all available information, in an understandable and accessible manner, in order to make informed decisions. This is of paramount importance as the issues surrounding traditional/country food in the North are becoming increasingly complex.

This project conducted work to address two gaps in our understanding of managing and implementing decisions surrounding contaminants and food in the North, namely how better to involve information on the cultural and social aspects of traditional/country foods in the North, and to gain a better understanding of the determinants of food choice in order to better orient advisory and intervention activities as well as diet-related health promotion programs. Work conducted to address each of these two items is presented separately in this report, each followed by a presentation of general conclusions and implications for making decisions on diet and health in the North.

Part A: Considering the Social and Cultural Aspects of Traditional/Country Food in Decision-Making Processes

Activities in 2000-2001

In the first year of this project, a literature review was conducted to identify and organize the social, cultural and spiritual benefits associated with traditional/country foods in the North. This literature review then formed the basis for the development of a conceptual framework in year 2 for the explicit consideration of the benefits and risks associated with traditional/country foods and traditional/country food-related activities in decision-making processes. A review of processes and methods to assess the social and cultural impacts of changes in traditional/country food-related activities was conducted.

A review of contemporary risk management frameworks for environmental health was also conducted in cooperation with another project in which C. Furgal participated (see Jardine et al. 2000). Based on this review and expert consultation with northern health and environment officials, recommendations are made for methods and placement in the decision-making process to explicitly consider social and cultural benefits and risks of traditional/country foods and traditional/country food-related activities.

Results and Discussion

The work conducted under year 2 of this project followed a basic line of inquiry common to impact assessment in order to understand the social and cultural aspects of traditional/country foods in the North and how this information is currently treated in decision-making processes. These questions included: What is the relationship between traditional/country foods and the social, cultural and spiritual well-being among Aboriginal peoples in the North? What are the broad categories of potential impacts of environmental contaminants in the Arctic and where do the social and cultural importance of traditional/country foods and their related activities fit in this hierarchy? Are the social and cultural impacts of advice based on contaminants issues currently considered when making decisions on health and the environment in the North, and if so, how? Is there a need to include these aspects in decision-making processes on traditional/country foods and health? How should it be done and what are the challenges to their inclusion? and, How do we overcome these challenges?

Table 1 outlines the effects that certain traditional/country food-related activities have on specific aspects of social, cultural or spiritual well-being in northern communities, as reported in the literature. The collection, consumption, distribution and preparation of traditional/country foods are reported to define, maintain, express and increase aspects of social, cultural and spiritual well-being in the North. Distinct benefits are reported as being associated with individual activities (collection, distribution, preparation or consumption of traditional/country foods), and thus an appreciation for these activities and the unique benefits each contributes to social, cultural and spiritual health must be recognized when making decisions. Little work has been done on the specific aspects of cultural and social importance of these foods; many studies simply report the general significance – but with little empirical support or detail in their argument. However, a specific treatment of this issue is complex as the nature of the social, cultural or spiritual relationships to traditional/country foods are not easily identified, described or measured. Such a description would be valuable to help understand the specific benefits and impacts of change in relation to traditional/country food related activities. Following the identification of these relationships and their importance, it is necessary to identify how they relate with other aspects of the relationship between individuals and traditional/country foods and the environment in northern communities.

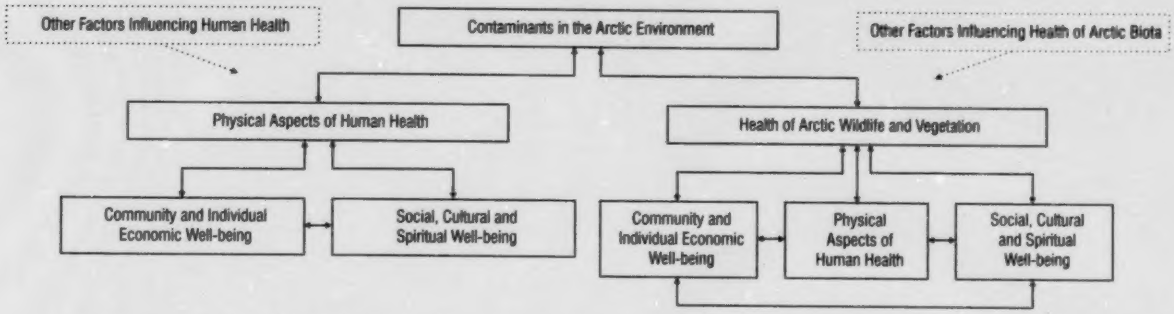
Table 1. Specific categories describing significance of traditional/country foods in northern communities as identified through a literature review

Activity	Significance	Theme or Aspect of Significance	Effect on Theme or Aspect
Collection	Cultural	Community	Continuity and expression
Consumption	Social	External influence	Definition
Distribution	Spiritual	Heritage	Increase
Preparation		Identity	Maintenance
		Individual	
		Well-being	

Figure 1 provides a simplified overview of the broad categories of direct and indirect impacts of the presence and public awareness of contaminants in the Arctic ecosystem. Human exposure to environmental contaminants in the Arctic ecosystem has potential impacts on physical and mental attributes of human health. The knowledge of this contamination and its potential impacts causes Northerners, northern health and environment practitioners, and managers to attempt to minimize this exposure and protect public health (e.g. health advisory or consumption advice). Both the potential effects of contaminants and the effects of the actions to minimize human exposures to them have potential impacts on human health, community and individual economic status, and community and individual social and cultural well-being. In all cases, impacts refers to either positive or negative change. Because of their interconnected nature, impacts to one of economic, physical health, or social-cultural well-being has indirect impacts on the others.

Similarly, the presence of contamination in biotic components of the Arctic ecosystem (specifically, in wildlife species consumed by Northerners) has potential impacts on aspects of environmental change in the North (e.g. potential impacts to fertility, reproductive success and general wildlife health resulting in changes in population size, human availability and access to traditional/country food species). The knowledge of this contamination, and attempts to minimize the impacts to wildlife and human health (e.g. through management

Figure 1. Simplification of impact assessment model (direct and indirect impacts) for Arctic contamination


Other Factors Influencing Human Health
Contaminants in the Arctic Environment
Other Factors Influencing Health of Arctic Biota
Physical Aspects of Human Health
Health of Arctic Wildlife and Vegetation
Community and Individual Economic Well-being
Social, Cultural and Spiritual Well-being
Community and Individual Economic Well-being
Physical Aspects of Human Health
Social, Cultural and Spiritual Well-being

→ Denotes action/reaction based on knowledge of contamination, or change in status of the compartement because of effect of contamination over time.

strategies, changes to hunting guidelines, and human consumption advisories or advice) have potential impacts on human health, community and individual economic well-being, and community or individual cultural and social health, with indirect impacts resulting because of their interrelated nature. Finally, simply the knowledge and awareness of contaminants in the Arctic environment have potential social, cultural and mental health impacts because of Northerners' close relationship with the land. This knowledge and awareness comes from reception of various forms of communication from both inside and outside the community, region, and country related to the issue of contaminants in the North.

Currently, direct and indirect human health impacts via numerous exposure pathways to contaminants are assessed and quantified through risk analyses conducted as part of the human health risk assessment process (e.g. Dewailly et al. 1998, Jardine et al. 2000) and these results are then available for consideration in the risk management process. Similarly, economic impacts and benefits are quantified, where data is available, through cost benefit analyses (e.g. Dewailly et al. 1998, Jardine et al. 2000) and can be made available for decision making regarding traditional/country foods in the North. Consideration for social and cultural benefits and risks, however, is conducted informally as part of the risk management process during consideration of what actions to take. No formal process is recognized for the assessment and analysis of potential social and cultural impacts of actions to minimize risks from exposure to environmental contaminants (Furgal 1999). Consideration of these factors is dependent upon the composition and experience of risk managers and others involved in the decision-making process. Further, the qualitative nature of these aspects presents certain challenges to their explicit inclusion. Additionally, the lack of understanding of specific social and cultural impacts limits the availability of this data – qualitative or quantitative – for consideration in decision-making processes that are often challenged by time, resources available to gather information, and inter-agency and organizational coordination and jurisdiction issues. Despite this, cases reviewed in Labrador, where these data were explicitly involved in the decision-making process surrounding contaminants in traditional/country foods, showed that this information had a significant positive impact on the resulting action taken. This is in contradiction to cases in which the indirect social and cultural impacts of actions to minimize human exposure were not anticipated and the results had significant negative social and health implications for the population involved (e.g. Broughton Island, as in Kinloch et al. 1992; and Sugluk, as in Wheatley and Wheatley 1981). The documentation of these negative impacts supports a strong argument for work into how and when to include this information in risk management processes.

The evolution of processes and methods for impact assessment of large development projects in the North can teach us a great deal about how to include qualitative social and cultural impact data in making decisions on traditional/country foods and health. Methods and processes of social impact assessment have evolved out of the recognized need to assess the social consequences of projects, programs, and government policies on communities and individuals (U.S. Department of Commerce 1994). Methods and processes have been developed and documented for these purposes (e.g. Finsterbusch et al. 1983, Brudge 1994). The monitoring and projection of changes in quantifiable indicators (e.g. reports of social pathologies, cases of depression, etc.) or the specific identification of qualitative relationships between factors within the community and aspects of social health and well-being are the most common forms of data included in social impact assessments. In these cases, "impacts" can be either positive or negative, direct or indirect changes. They can include such things as exposure to new risks or benefits, and/or decrease in exposure to current risks or loss of current benefits. It is the last form of social and cultural impacts that is perhaps most important for the case of changes imposed by actions to minimize human exposure to contaminants in traditional/country foods. Similar to processes of risk assessment and management, the social impact assessment process stresses the need to involve a diverse public (as it is about addressing concerns of the public), analyze impact inequities (to be specific regarding which segments of the population are impacted the most), focus the assessment (to take into account "concerns that really count, not those that are just easy to count"), identify methods and assumptions (to be clear on uncertainties and biases), define the significance of variables impacted, establish monitoring and mitigation programs (plan for the unexpected and follow up on activities), identify data sources, and plan for gaps in data (National Environmental Protection Agency 1998). However, to include consideration for these impacts in decision-making processes on human health exposure to contaminants requires certain forms of information. Baseline data (qualitative or quantitative) on specific relationships between social and cultural well-being and traditional/country foods and an understanding of these relationships and the factors influencing them is required. Development of qualitative or quantitative indicators of the relationship between social and cultural well being and traditional/country foods is also needed (e.g. what is the relationship between social health status indicators and level of hunting, or traditional/country food sharing activity in communities?). Retrospective analyses of changes in social and cultural well-being induced by similar or the same factors (advisories or intervention programs) in other locations must be conducted and made available in order to project potential changes of future activities. Without the development and availability of this detailed information, it is impossible to expect consistent and appropriate consideration to be given to these important aspects of the issue in all decision-making processes. Currently, risk management processes are frequently challenged by time, resources (financial and human), uncertainty and availability of data, and organizational and jurisdictional complexities.

When to include consideration for potential social and cultural impacts of a decision is an important aspect to mention. As outlined in Figure 1, for our purposes, social and cultural impacts of contaminants are a direct result of either contaminant-related changes in wildlife availability and accessibility (health and numbers), or actions taken to minimize human exposure to contaminants in the environment. Indirect social and cultural impacts result from increased awareness and perceptions and/or misconceptions of contaminant related risks, or indirect impacts of actions taken to minimize human exposure (i.e. impacts of changes in economy because of action). This understanding designates where in the risk mana0-gement process information on social and cultural impacts is most appropriately presented and considered. Shortreed et al. (2000, as reviewed in Jardine et al. 2000) developed a composite "benchmark" risk management framework through comparing and contrasting all international frameworks currently available (Figure 2). In this process, the consideration for social and cultural benefits and risks of traditional/country foods is best included in the discussion when determining and assessing potential actions to take to minimize human exposure.

Part B: Application of the Survey Tool to Measure Determinants of Food Choice in the North

Activities in 2000-2001

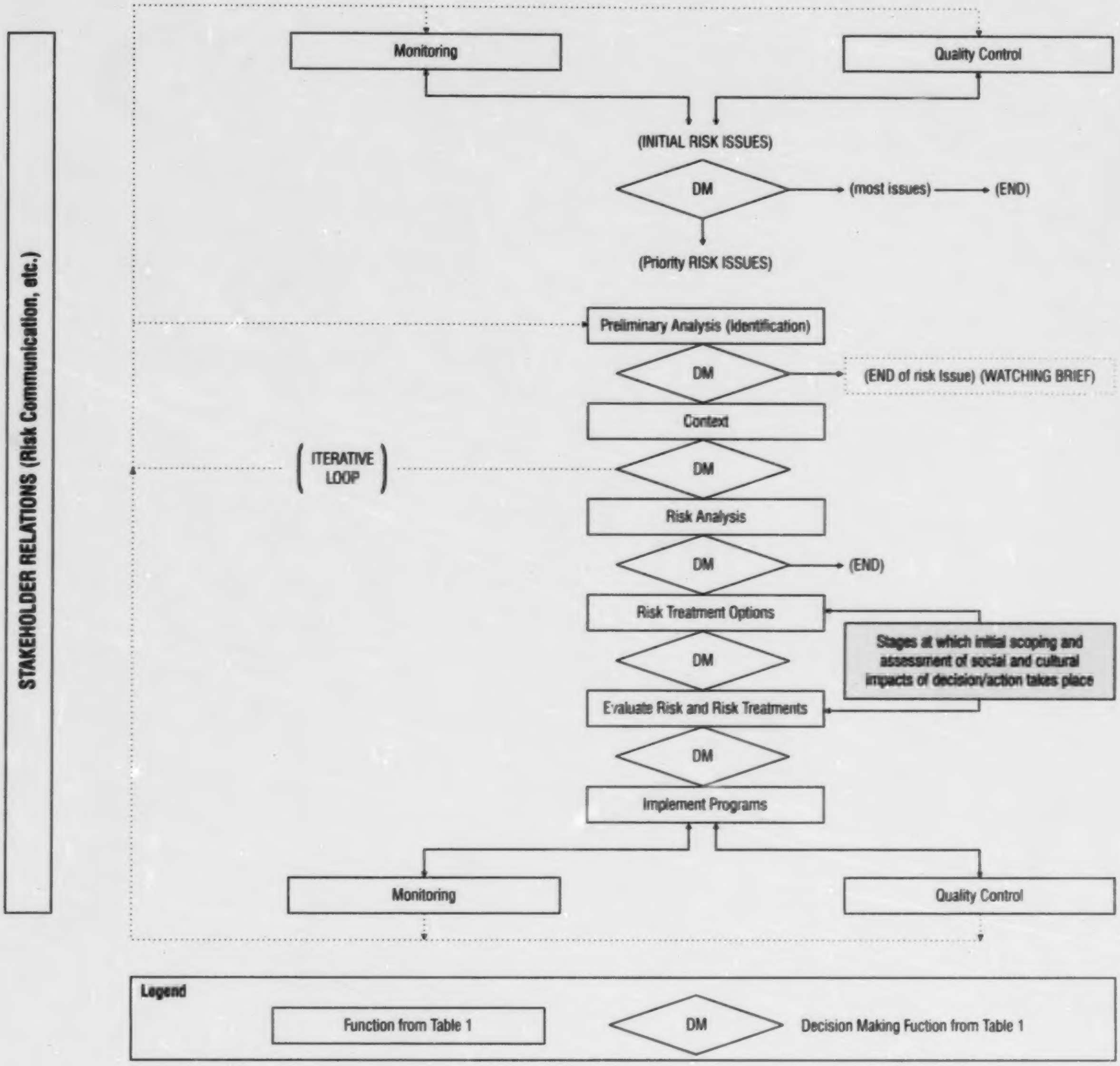
Data collection

The application of the survey tool developed in year 1 was successfully completed on February 27, 2001. One member of our research team, a research assistant and 14 local interviewers, completed 251 interviews with Inuit residents of Kuujjuaq, Nunavik, 12 years of age and older. The questionnaire was tested and retested in both English and Inuktituut with 39 residents of Kuujjuaq and was then further adapted following statistical analysis for each question's validity and the survey's reliability. Composed of 50 questions, it measured frequency of use of foods, constructs of Triandis' theory for use of traditional/country food three times a week or more, use of store-bought food every day, degree of liking of foods, as well as basic socio-demographic information (see Table 2). The project and consent forms were reviewed and approved by the Ethics Committee of Laval University Hospital Centre and the Nunavik Nutrition and Health Committee. Informed consent was obtained from all participants after having explained the objectives of the survey.

Data coding and treatment

All questionnaire forms were reviewed and validated to eliminate logic or coding errors and all data for statistical analysis was captured twice. Statistical analysis was conducted using Statistical Analysis System (SAS) software (Statistical Analysis System Institute Inc. 1999). The mean score of the participants, according to age, on each construct was compared using analysis of variance,

Figure 2. Overview of Benchmark (composite) Risk Management Framework*


STAKEHOLDER RELATIONS (Risk Communication, etc.)
Monitoring
Quality Control
(INITIAL RISK ISSUES)
DM
(most issues)
(END)
(Priority RISK ISSUES)
Preliminary Analysis (Identification)
DM
(END of risk Issue) (WATCHING BRIEF)
Context
ITERATIVE LOOP
DM
Risk Analysis
DM
(END)
Risk Treatment Options
DM
Stages at which initial scoping and assessment of social and cultural impacts of decision/action takes place
Evaluate Risk and Risk Treatments
DM
Implement Programs
Monitoring
Quality Control
Legend
Function from Table 1
DM
Decision Making Fuction from Table 1

* Source: Shortreed et al. 2000

and Scheffe's test was used for pair-wise comparisons. The mean score of the participants on each construct according to gender was then compared using Student's *t*-test. The relationship between the intention to eat traditional/country food or store-bought food), and constructs was evaluated by linear regression analysis (standardized estimate for each construct and the adjusted r^2 for the model are presented). The relationship between the past behaviour to eat traditional/country food and constructs was evaluated via logistic regression. The relationship between intention to eat traditional/country food and barriers or facilitating factors was also evaluated using logistic regression (Kleinbaum 1988)

Results

Participation

One hundred and seven (107) men and 143 women completed the questionnaire, with overall response rate of 87.76%. Although an attempt was made to use stratified random sampling only 197 of the participants were randomly selected while the remaining 54 were opportunistic

Table 2. Questionnaire summary

Constructs	# Items		Example
	CF[1]	SBF[2]	
Normative belief[3]	6	6	How often do your parents tell you to eat CF? (4-point frequency scale: rarely/never – most of the time)
Emotion[3]	2	3	If you ate SBF every day, would you get tired of it? (5-point probability scale: no – yes)
Attitude[3]	6	6	If you ate CF ≥ 3 times/week, would it be unpleasant-pleasant (5-point semantic differential scale)
Intention[3]	2	2	Over the next month, do you plan to eat SBF every day? (5-point probability scale: no – yes)
Perceived behavioural control	3	2	How easy would it be for you to eat SBF every day? (5-point semantic differential scale)
Personal normative beliefs[3]	1	1	Do you think you should eat CF because you grew up with it? (5-point scale: disagree – agree)
Behavioural beliefs[3]	6	7	If you ate SBF every day, do you believe it would as fulfilling as CF? (5-point probability scale)
Self efficacy[3]	12	8	Would you eat CF ≥ 3 times/week if there was some at the community freezer? (5-point scale : no – yes)
Role belief[3]	1	1	As part of being Inuk, do you think you should eat CF? (5-point scale: totally disagree – totally agree)
Perceived behavioural norm	6	7	How often do you think kids eat CF? (4-point frequency scale: rarely/never – most of the time)
Degree of liking	1	1	Rating of taste of CF and SBF (10-point scale: not at all – like very much)
Use of foods	1	1	Yesterday: Foods used (dichotomous: yes/no)
	1	1	Last week: Frequency of use of CF and SBF (4-point frequency scale: 0 – every day)
	1	1	Usually: Frequency of use of CF and SBF (6-point frequency scale: never – every day)
Place of use and frequency	5	6	Place foods are consumed. E.g. at home, in restaurant (4-point scale: rarely/never – most of the time)
Use of community freezer	1	0	Frequency of use (4-point frequency scale: rarely/never – most of the time)
One open question on other reasons for eating traditional/country food and store-bought foods			

[1] Number of items (questions) to measure each construct in relation to traditional/country food (CF)

[2] Number of items (questions) to measure each construct in relation to store-bought food (SBF)

[3] Constructs of Triandis's theory

interviews. Interviewers interviewed people they knew as well as those participants previously randomly selected. A total of 29% of the eligible population was surveyed. Analysis was conducted on results from 239 participants, as 12 questionnaires had missing values (Table 3). A participant's questionnaire was rejected if > 33% of the questions composing a single construct were unanswered.

Results for each construct

Table 4 shows participants' mean score on each construct (composed of the average score of 1 to 12 questions). For example, on a probability scale of 1 to 5 (No – Yes) and using a composite score of six questions, the mean score for eating traditional/country foods three times per week or more for the whole sample was 4.52 (SD = 0.56) for the construct "behavioural beliefs".

Results for each construct according to age and gender

Means and standard deviations according to age for the behaviour to eat traditional/country food three times a week or more are presented in Table 5. Significant differences in participants' scores on all but two constructs were found between age groups for the behaviour to eat traditional/country food. No significant differences were found according to gender for this data. Significant differences observed are between the 13- to 19-year-old group and all others (20 to 30, 31 to 40, ≥41), and between the 12- to 19- and 20- to 30-year-old groups, and all others (31 to 40, ≥41).

Variance explained by each determinant on intention

Perceived behavioural control (how easy or difficult a person perceives adopting a behaviour would be) is the strongest predictor of intention to eat traditional/country food three times a week or more, while personal normative belief (personal feeling of obligation to adopt the behaviour), followed by emotion (personal feelings associated with the behaviour) and perceived behavioural control, are the best predictors of intention to eat store-bought food every day. Knowledge of contaminants was not a determining factor of intention. Table 6 shows the regressions of intention to eat traditional/country food and store-bought food on the predictor variables. Of the 12 constructs examined for their part in explaining the variance observed in the sample, five play a significant

Table 3. Composition of participants according to age and gender

Age	Men	% of sample	Women	% of sample	Total	% of sample
12-19	22	9.21%	39	16.32%	61	25.52%
20-30	27	11.30%	38	15.90%	65	27.20%
31-40	48	20.08%	55	23.01%	103	43.10%
≥ 41	4	1.67%	6	2.51%	10	4.18%
Total	**101**	**42.26%**	**138**	**57.74%**	**239**	**100.00%**

Table 4. Average score of the sample for each construct (composite score of n items) used to measure intention to eat traditional/country food and store-bought food (n = 239)

Construct	# of questions per construct	Scale[1]	Eat CF[2] ≥ times/week Mean ± Standard Deviation	# of questions per construct	Scale[1]	Eat SBF[3] every day Mean ± Standard Deviation
Habit	1	1-4	2.44 ± 1.13	1	1-4	3.03 ± 0.93
Perceived behavioural norm	6	1-4	3.21 ± 0.43	7	1-4	2.75 ± 0.53
Normative belief	6	1-4	1.93 ± 0.69	6	1-4	1.74 ± 0.62
Emotion	2	1-5	4.35 ± 0.82	3	1-5	2.49 ± 1.05
Role belief	1	1-5	4.18 ± 0.85	1	1-5	3.00 ± 0.95
Behavioural belief[4]	6[4]	1-5	4.52 ± 0.56	7[4]	1-5	2.50 ± 0.76
Intention	2	1-5	4.15 ± 0.92	2	1-5	3.27 ± 1.27
Perceived behavioural control	3	1-5	4.27 ± 0.63	2	1-5	3.71 ± 1.02
Personal normative belief	1	1-5	4.02 ± 0.91	1	1-5	3.00 ± 1.55
Attitude	6	1-5	4.16 ± 0.41	6	1-5	3.43 ± 0.65
Self-efficacy	12	1-5	3.73 ± 0.63	8	1-5	2.47 ± 0.83
Taste	1	1-10	8.83 ± 1.54	1	1-10	6.97 ± 2.00

[1] Scales ranged from a negative response to a question to a positive response (e.g. Attitude: 5-point semantic-differential scale, Very unhealthy – Very healthy; Intention: 5-point probability scale, No – Yes; Normative belief 4-point frequency scale, Rarely/never – Most of the time

[2] Traditional/country food

[3] Store-bought food

[4] Composite score of n questions (e.g. mean of 6 questions for traditional/country food and 7 questions for store-bought food used to measure behavioural belief)

role in explaining the variance in intention to eat traditional/country food three times/week or more over the next month, while six of them explain the variance in intention to eat store-bought food every day over the next month. Combined, the determinants identified in the course of this study explain 49% of the variance in individual intention to eat traditional/country food and 62% of the variance in their intention to eat store-bought food.

Association between each construct and past behaviour (habit)

Emotion ($p = .0005$), followed by perceived behavioural control ($p = .027$) and personal normative belief ($p = .044$) about eating traditional/country food three times/week or more were significantly correlated with past behaviour/habit.

Association between barriers/facilitating factors and intention

It is assumed that perceived behavioural control reflects external factors (e.g. barriers such as cost, availability) as well as internal factors (e.g. attitude, feelings, beliefs) (Godin and Kok 1996). Therefore, considering the significance of this factor in explaining the variance in intention here, we proceeded to verify the association between each external factor measured and intention (as a dichotomous variable – high/low intenders). Of the 12 factors tested,

Table 5. Average score of the sample for each construct predicting intention to eat traditional/country food ≥ 3 times/week over the next month, according to age

Variables	Mean ± Standard Deviation 12-19 years old (n = 61)	 20-30 years old (n = 65)	 31-40 years old (n = 52)	 ≥ 41+ years old (n = 61)	p
Habit	$1.95 \pm 0.92^{a*}$	$2.14 \pm 1.16^{a*}$	$2.85 \pm 1.07^{b*}$	$2.92 \pm 1.04^{b*}$	< .0001
Personal normative belief	3.95 ± 0.86^{ab}	3.71 ± 0.98^{a}	4.19 ± 0.84^{b}	4.26 ± 0.85^{b}	.002
Normative belief	2.77 ± 0.62^{a}	1.83 ± 0.64^{ab}	1.78 ± 0.60^{b}	1.93 ± 0.83^{ab}	.011
Emotion	4.11 ± 0.94^{a}	4.25 ± 0.87^{ab}	4.45 ± 0.70^{ab}	4.62 ± 0.64^{b}	.003
Role belief	4.00 ± 0.88^{a}	4.11 ± 0.73^{a}	4.25 ± 0.81^{a}	4.39 ± 0.95^{a}	.061
Behavioural belief	4.19 ± 0.66^{a}	4.58 ± 0.48^{b}	4.68 ± 0.42^{b}	4.65 ± 0.49^{b}	< .0001
Intention	3.93 ± 0.91^{a}	3.85 ± 0.96^{a}	4.40 ± 0.71^{b}	4.47 ± 0.48^{b}	< .0001
Perceived behavioural control	4.04 ± 0.75^{a}	4.18 ± 0.49^{ac}	4.51 ± 0.45^{b}	4.40 ± 0.69^{bc}	.0002
Attitude	4.02 ± 0.40^{a}	4.10 ± 0.38^{a}	4.20 ± 0.36^{ab}	4.33 ± 0.41^{b}	.0002
Perceived behavioural norm	3.11 ± 0.33^{a}	3.16 ± 0.45^{a}	3.33 ± 0.42^{a}	3.28 ± 0.48^{a}	.018
Self-efficacy	3.73 ± 0.68^{a}	3.62 ± 0.66^{a}	3.78 ± 0.54^{a}	3.79 ± 0.60^{a}	.391
Taste	8.25 ± 1.73^{a}	8.78 ± 1.57^{ab}	9.02 ± 1.49^{ab}	9.29 ± 1.15^{b}	.001

* Different letters indicate statistically significant differences (e.g. habit: statistical differences found between 12-19 and 31- 40, 12-19 and ≥ 41, 20-30 and 31- 40, 20-30 and ≥ 41 age groups)

Table 6. Regressions of intention to eat traditional/country food and store-bought food on predictor variables

Combined model	Eating CF[1] ≥ 3times/week over the next month (n = 239) β	 r^2 adjusted	Eating SBF[2] every day over the next month (n = 239) β	 r^2 adjusted
Attitude	0.12[3]		n.s.[4]	
Habit	0.12[3]		0.15[3]	
Emotion	0.15[5]		0.27[6]	
Perceived behavioural control	0.40[6]		0.26[6]	
Personal normative belief	0.14[5]		0.31[6]	
Taste	0.10		0.11[3]	
Role belief	n.s.		0.09	
Self efficacy	n.s.	0.49[7]	-0.14[5]	0.62[7]

[1] Traditional/country food

[2] Store-bought food

[3] $p < .05$

[4] Not significant

[5] $p < .01$

[6] $p < .001$; to be included, a variable must add at least 1% of variance to the model.

[7] For the behaviour to eat CF, 49% of the variance observed is explained by the five significant constructs; for SBF, 62% of the variance observed is explained by the six significant constructs.

three were significantly related to intention. Having someone share traditional/country food with (p = .008), having to hunt or fish for traditional/country food (p = .040) and having access to traditional/country food through the Hunter Support Program/community freezer (p = .0005, strongest association) were all significantly correlated with intention.

Results to questions related to health and safety value of traditional/country food

When asked if eating traditional/country food three times per week or more over the next month would be very good for their health (measure of belief), 92.05% of participants responded probably/yes. When asked if they believed it would make them sick, 87.03% responded probably not/no. When asked if eating traditional/country food three times/week or more over the next month would be healthy/unhealthy (measure of attitude), 94.14% of participants thought it would be healthy/very healthy. When asked if this behaviour was safe or unsafe, 90.38% responded that they thought it would be very safe/safe.

Discussion

The methods used in the first year of this study (Dewailly et al. 2000), to elicit the emic views of the etic constructs, contributed to the quality of our questions in the year 2 survey. The questionnaire was built from local knowledge and language, tested and retested, and further adjusted so it was easy to understand and answer. No questions in the applied survey were considered inappropriate or irrelevant by participants and thus the number of non-responses was very low. Also, including an open-ended question at the end of the questionnaire allowed us to further ensure that we covered all possible answers in the previous questions as no new or different attributes were reported here. In viewing Table 4, we notice that all scores but one are higher (more positive) for traditional/country food than store-bought food. Habit was the only construct scoring higher (more positively) for store-bought food. Does this mean that intention is overrated? This result may be due to the fact that the actual behaviour is also influenced by environmental factors such as reinforcements and facilitating conditions (Godin 1991). The answer to our question is probably in the amount of unexplained variance in our data. Differences between age groups in this data were expected since differences in consumption are also found in results from diet survey literature. However, we noted two types of differences in this data. Sometimes the dividing line falls between the teenagers and the adults or between teens/young adults and the rest of the population. This provides more detail on the differences between age groups beyond the teenager/adult comparisons regularly reported.

To predict behaviour, instead of intention, it would have been necessary to measure behaviour in this study, however, this was not possible. Instead, we rely on our proxy measurement for behaviour, which is intention. Metanalyses have shown intention to be the best proxy for behaviour (Godin and Kok 1996, Sutton 1998) but they have also shown that the amount of variance explained increased significantly when including a measure of perceived behavioural control. In this study, we improved upon this further through the inclusion of both perceived behavioural control and habit. Habit explained part of the variance in our data but perceived behavioural control came out as the strongest predictor. A test was also conducted to verify the relationship between the determinants and habit (also used as a proxy of behaviour even though it is also a predictor of intention). However, to have the best power of prediction we should have measured behaviour at the same level of specificity and not as a measure of past habit (Sutton 1998). This result is further limited by the fact that both variables were measured on different scales (continuous/dichotomous) and this has been shown to attenuate correlations (Courneya 1994). We can show the following factors have a significant association with habit: emotion, perceived behavioural control and personal normative belief (in order of decreasing strength of the relationship). We can not compare our results from the multiple regressions on intention with our logistic regressions on habit but we are able to identify which factors are the most important for each construct. For intention, they are perceived behavioural control, emotion, personal normative belief, habit, attitude (in decreasing order of strength).

When looking at the results of the influence of barriers/facilitating conditions on intention (having someone share traditional/country food with you, having to hunt/fish for traditional/country food and having access to traditional/country food through the Hunter Support Program/community freezer), it is interesting to view these results in combination with the results from the question on use of the community freezer; 82% of the participants reported sometimes/often/most of the time getting traditional/country food from the community freezer. This is an important issue to consider in relation to compliance to health advisories on the consumption of traditional/country foods, should any be conducted in the future.

In our survey, only three questions addressed the issue of the effect of contaminants on food choices and our results indicate that there is no effect. Two of the three questions on this issue were included in the composite measure of attitude (which did not come out as a major determinant of choice) and one was included in the measure of behavioural beliefs (and did not come out as a major determinant either). Although these are not specific questions on contaminants, we believe the fear, or lack of fear for contaminants in traditional/country foods are filtered through the measure of attitude which was included in this study. It must also be emphasized that the methods used to build the survey aimed to elicit, through focus group interviews, *salient beliefs* about the consumption of traditional/country food and store-bought food. This was done using very general elicitation questions. Therefore, if contaminants was not brought up by participants, it was not considered a salient concern and therefore not included as a specific question in the questionnaire (this protects the researcher from the situation of "suggesting" responses to the participant). With this study, we aimed to go beyond simply asking people to agree with predetermined statements. The only comments made regarding disadvantages of traditional/country food in this study concerned food poisoning from preparation of *igunaq* or from zoonoses in raw meat. Participants had multiple opportunities to express their concerns during the test-retest since, for each question, precise reasons for answering in one way or another were requested. Although we recognize that all methods have limits in what information they elicit, we believe that if concern for contaminants was an issue *when faced with the decision to eat traditional/country food or not (as the question was posed in this survey)*, it would have come out more often in participants responses.

Conclusions

This study addressed two identified gaps or challenges in the effective management and communications related to contaminants and traditional/country food in the North. In fact, in many respects this study has gone beyond its original goals as it has provided direction for future work in the areas of social impact assessment and indicators related to social and cultural well-being in relationship to traditional/country food and traditional/country food related activities. Additionally, it has provided a basis of understanding of diet related behaviour in a northern community. This is the first quantitative data of its kind in a region where significant influences to, and changes in, diet have been observed in the last few decades and appear to be continuing into the future. Some of the shifts in diet have significant health implications. These results are intended to help health and environment officials in managing contaminants and health issues and in planning promotion or prevention activities to effectively target specific groups based on specific diet-related behaviours. If the objective of health advice and advisories is to inform people of the potential human health effects of exposure to certain contaminants through the consumption of traditional/country foods, general communication methods are most appropriate. However, if the desired effect is to change behaviour, planning an intervention based on changing the perception people have of how easy or difficult it is to increase or decrease their consumption of a certain traditional/country food will have a greater chance at achieving the program goal. For example, to promote the consumption of Arctic char among pregnant women in Nunavik, the Nunavik Nutrition and Health Committee made access to char easier for this group of the population. Another example might be the hypothetical case of a recommendation to decrease consumption of a specific traditional/country food that is met with non-compliance. The results of this study suggest that an argument based on the provision of health information alone would have little chance in changing behaviour if this traditional/country food was available for free through the community freezer or at other sources in the community (i.e. people do not choose their food solely on the basis of their value to health). The issue of ease of access would need to be considered in the development of the intervention strategy or release of health advice and expected outcomes.

Project Completion Date

March 31, 2001

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Food Choice Decisions by Western Arctic Aboriginal Women and Children, Year 1

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Abstract

Factors influencing food choices by Aboriginal women and children, and children's dietary patterns were investigated in five Western Arctic Communities: three in the Northwest Territories and two in the Yukon. Research tools included focus groups, interviews of women, and dietary interviews of children aged 10 to 12 years. Data are now being entered into databases. These preliminary data revealed 28 factors influencing food choice that can be placed into five broad categories; the cost of food and food availability were the two most important categories of factors reported by women. Contaminants were rarely mentioned as a reason why people selected, or would not select, one food or another. Additional interviews will be conducted in 2001-2002.

Key Project Messages

1. Leaders and participants in meetings of the Dene Nation and the Council of Yukon First Nations as well as Aboriginal women and 10- to12-year-old children in five Western Arctic communities were asked questions about food choice decisions during the summer and autumn of 2000.
2. Preliminary data revealed 28 factors influencing food choice. These can be grouped into five broad categories. The cost of food and food availability were the two most important categories of factors reported by women respondents. Contaminants were rarely mentioned as a reason why people selected, or would not select, one food or another.
3. Interviews will continue during 2001-2002 to further investigate these preliminary findings.

Objectives

1. To understand the larger picture of factors influencing food choice decisions by Arctic women and children, so that risks and benefits messages can be placed in relevant and appropriate context for effective education messages.
2. To understand children's use of traditional and market food.

Introduction

Extensive dietary and sociocultural information are available for adults in Dene/Metis and Yukon First Nations communities. However, in order for this information to be useful to Aboriginal organizations and public health agencies responsible for food and nutrition education efforts that address benefits and risks of food use, the context of food choice decisions in the community setting are needed. As well, since food behaviour is learned, it would be helpful to understand how children use traditional and market food in these communities. It is clear in the global literature, that factors influencing personal food choice decisions must be known before effective food education interventions can be planned carried to effective completion (Ross 1995, Parraga 1990, Rappaport et al. 1992).

This is a report on the first year of a 2-year project.

Activities in 2000-2001

Following a review of our existing data on food use and sociocultural factors influencing food use, discussions were held with staff of the Council of Yukon First Nations and the Dene Nation to generate a tentative list of food choice factors, and to enlist support for the project. Of several communities in Denendeh and Yukon that requested participation, five communities were selected: Fort McPherson, Tulita, Fort Resolution, Carcross and Old Crow. Ethics approval was given by McGill University, science licenses were obtained and research agreements with each community were signed.

Field work was conducted in each of these communities from late November 2000 to the end of January 2001. Five focus groups were held (one in each community) with a total of 24 participants, and dietary interviews of 10- to 12-year-old children were conducted (n = 115), with about 85% of children giving repeat 24-hour recall interviews during the winter season. Interviews with women who are mothers and/or caregivers of these children and who participated in the focus groups were conducted. In all, 20 interviews were conducted with women who participated in the focus groups, and 13 additional interviews (Fort Resolution, Old Crow, Carcross) were conducted for the purposes of ranking food choice factors. At this time, focus group data are in the process of transcription, and dietary data are being entered into a database.

Discussion and Conclusions

Twenty-eight factors responsible for food choices were identified and were placed into five major categories: costs (in the broadest sense); availability (of both traditional and market food); cultural and pleasurable reasons for selecting food; physical and medical reasons (age, gender, appetite); and knowledge (traditional knowledge, contaminants, labels). Preliminary information from the focus groups identified costs and availability of food as the most important factors for food choices in these communities. Contaminants were rarely mentioned as a reason why people selected, or would not select, one food or another. Interview information to be gathered during 2001-2002 will further investigate these preliminary findings.

Expected Project Completion Date

March 2002

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Nutrient Benefits of Arctic Traditional/Country Foods

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Abstract

Food items known as traditional/country foods of Arctic Aboriginal peoples, and that are considered favorite or unique foods, or that were frequently consumed as determined during a dietary evaluation study, were sampled and analyzed for several nutrients. Reported here are selected analyses prioritized by foods and nutrients, and the need for additional data. Most of the values reported here are first reports of these nutrients in these foods. Nutrient data from this study are now incorporated into a database used for nutrient analysis of dietary records of Arctic Aboriginal peoples. New data are presented for fatty acids, proximate composition, minerals and vitamin D. These data contribute substantially to the existing traditional/country food composition database. Knowledge of nutrient contents in Arctic traditional/country food is important for nutrition education initiatives of Aboriginal peoples, and for understanding global food diversity.

Key Project Messages

1. Several unique traditional/country food items of Arctic Aboriginal peoples were analyzed for their nutrient contents. Foods such as fat made from caribou bone and grizzly bear bone, caribou bone marrow, caribou brain, seal and walrus liver, fish roe, whale skin, berries and spruce sap were collected from Arctic communities in partnership with local residents familiar with these foods.
2. Arctic traditional/country foods are rich sources of nutrients.
3. Burbot liver is an excellent source of vitamin D, as is Arctic char and beluga fat.
4. Most Arctic foods are good sources of monounsaturated and polyunsaturated fatty acids.
5. General mineral levels in animal flesh foods are high; consuming these foods can contribute to good health.

Objectives

1. To provide new knowledge of nutrients in traditional/country foods frequently consumed by Arctic Aboriginal peoples.
2. To provide new knowledge of nutrients in favorite or unique traditional/country food items consumed by Dene, Metis, Yukon First Nations and Inuit.
3. To fill in gaps in the existing nutrient composition database resulting from inadequately sampled food items.

Introduction

The Human Health Blueprint of the Northern Contaminants Program recognizes that benefit-risk assessment must include nutrient information on food consumed. Arctic diets are composed of both traditional/country and market food items. While most market foods have known values for the spectrum of nutrients in human nutrition, the complete nutrient profiles of traditional/country food items are not available. There are many nutrients in Arctic foods for which nutrient levels are not known or are not completely known. This information is needed to make informed decisions weighing contaminant risks with multiple nutrient and sociocultural benefits of traditional/country food consumption in Arctic communities.

Further, nutrient compositions of traditional/country foods are in demand by nutritionists working with Arctic peoples in the areas of dietary evaluation, preparation of education materials and in individual counseling.

Projects carried out by the Centre for Indigenous Peoples' Nutrition and Environment (CINE) have assessed dietary benefits and risks in Dene/Metis, Yukon First Nations and Inuit communities (Kuhnlein et al. 2001). The traditional/country food items most frequently consumed were sampled, but often sufficient sample size or sample number were not. Therefore, this project attempted to obtain additional samples of frequently consumed foods, as well as important food items that had not yet been sampled but were suggested to be good sources of nutrients. Analyses of several nutrients were developed during the previous year, and continued during this project. Nutrient analyses of food samples were conducted for proximate composition (protein, fat, moisture, ash, carbohydrate-by-difference, computed energy), fatty acids (polyunsaturates, monounsaturates, saturates, sum of n-6 and n-3 fatty acids), minerals (calcium [Ca], iron [Fe], copper [Cu], zinc [Zn], phosphorus [P], magnesium [Mg], manganese [Mn], potassium [K], sodium [Na], selenium [Se]) and vitamins (A [retinol], E [alpha tocopherol], C [ascorbic acid], folic acid, B-2 [riboflavin], B-6 [pyridoxine]). The method for vitamin D was fully developed during this year and extensive work was conducted on fatty acids analyses of samples.

Activities in 2000-2001

The first activity was to prioritize samples for analyses of each nutrient, since it was prohibitive to analyze all samples for all nutrients. Prioritizing was done by reviewing the rank-order of traditional/country foods consumed in each of the three large surveys as reported in 24-hour recalls. Items reported consumed by ≥5 of the randomly selected adults were included in the prioritized list. Second, food items from this list without any nutrient data and for which samples were in hand were given priority. A final prioritization was made for each nutrient in each of the rank-ordered foods according to expectation of whether or not it would be a likely source of the nutrient (e.g. blubber or other pure fat samples were not analyzed for protein, minerals or the B vitamins).

Food samples were portioned for each nutrient and stored appropriately (e.g. as homogenates for vitamins, as freeze dried powders for minerals, as whole tissue for labile vitamins, etc.). Samples for vitamin analyses in the Health Canada (Health Protection Branch) laboratory were shipped on dry ice. Throughout this work, sea mammal mattak, a food with both blubber and skin, was dissected and analyzed separately as blubber or as skin (noted as mattak/skin). This was done because of the difficulties in assuming a consistent component of blubber and the very different nutrient contents of the two portions.

Nutrients were analyzed using standard methods (Behrens and Madere 1994, Esteve et al. 1998, Fellman et al. 1982 (modified), Helrich (ed.) 1990, Hidiroglou et al. 1993, Hoppner and Lampi, 1993, Hoppner and Lampi 1989, Horne and Patterson 1988, Kuhnlein and Soueida 1992, Kuhnlein et al. 1991, Mattila et al. 1992, 1993, 1995, Tamura 1998, Thompson and Hatina 1979). Data were compiled as unit$\cdot$100 g^{-1} food as consumed for ease of insertion in the dietary analysis database.

Results

Fifty-five samples of traditional/country foods were received from Inuit, Dene/Metis and Yukon First Nations areas. These included several samples of caribou bone marrow, lake trout, seal flesh, walrus blubber (fresh and aged), Arctic char, caribou flesh, seal liver, walrus liver, smoked and dried whitefish, cranberries, fat made from caribou bones, fat made from grizzly bear bones, caribou brain and clear spruce sap.

Due to delays, all the analyses on these samples have not yet been completed. In particular, several vitamin analyses are still to be completed at Health Canada. However, use of the laboratory staff and equipment were made to continue analyses of samples already in hand. Tables 1a and 1b report results of the fatty acid analyses of several Arctic foods that were still outstanding from the previous year.

It can be seen that several Arctic foods are excellent sources of fatty acids. The polyunsaturated fatty acids were highest in moose fat, salmon eggs and cooked flesh with fish samples having the highest n-3 fatty acids content. Saturated fatty acids were highest in moose fat, ooligan flesh and caribou kidney. Moose fat had very high monounsaturates content as compared to the rest of the samples reported here; beluga muktuk, ooligan flesh and salmon eggs followed.

New results for vitamin D in traditional/country Inuit and Yukon foods are reported in Table 2. Of the samples reported here, vitamin D content of burbot liver (318 $\mu g \cdot 100\ g^{-1}$) was approximately 12-fold higher than the next samples in rank (beluga oil and Arctic char flesh).

The proximate and mineral composition of recently analyzed new food items, which includes new samples not previously analyzed for these entities (grizzly bear grease, caribou bone grease, brain and bone marrow, walrus blubber and liver, moose liver, scoter meat and spruce sap), are given in Tables 3, 4a and 4b.

Discussion and Conclusions

The results of this project provide new nutrient data for Arctic traditional/country food items. These data are compatible with earlier reports on nutrient levels and contribute substantially to the nutrient composition database. These data also make a valuable contribution to benefit-risk assessment on the use of Arctic traditional/country foods, as it becomes clearer that these food items should be protected and included in the diet whenever possible. Computer modelling of benefit and risk can proceed with a better understanding of a more complete nutrient profile in contrast to contaminant content profiles of traditional/country food items. Additionally, there is still much to be learned about the disease prevention potential of these nutrients in Arctic diets and how they may contribute to the mediation of contaminant health effects. Continuing research is needed to address additional nutrients in these foods.

As noted in Burlingame (2000) and Kuhnlein (2000), the vast array of traditional/country food resources of Aboriginal peoples must be documented because of their important place in global nutrition and food diversity.

Table 1a. New data of saturated and monounsaturated fatty acid composition of several Arctic foods, listed alphabetically

Food Sample			Saturated Fatty Acids (g per 100 g)									Monounsaturated Fatty Acids (g per 100 g)						
Species and part	Preparation¹	n	8:0	10:0	12:0	14:0	16:0	18:0	20:0	22:0	24:0	12:1	14:1	16:1	18:1	20:1	22:1	24:1
Bearded seal, meat	boiled	1	nd²	nd	nd	0.2	0.6	0.2	nd	nd	nd	nd	nd	0.2	0.9	0.9	0.1	nd
Beluga, muktuk	boiled	1	nd	nd	0.2	1.0	1.1	0.2	nd	nd	0.3	tr³	0.4	3.8	3.8	1.5	0.1	nd
Black duck, liver	raw	1	nd	nd	tr	tr	0.6	0.4	nd	nd	tr	nd	tr	0.1	0.6	tr	nd	nd
Caribou, fetus (a.s.)⁴	raw	1	nd	nd	nd	0.0	0.2	0.1	tr	tr	tr	nd	tr	tr	0.2	tr	nd	tr
Caribou, kidney	raw	2	nd	nd	nd	0.1(0.08)⁵	1.1(1.2)	1.7(2.0)	tr	tr	0.1(0.001)	nd	tr	0.1(0.05)	2.0(2.6)	tr	nd	tr
Caribou, liver	raw	1	nd	nd	nd	tr	0.2	0.5	nd	nd	0.1	nd	tr	tr	0.3	nd	nd	nd
Caribou, meat	cooked	1	nd	nd	nd	0.1	1.4	1.0	nd	nd	0.1	nd	nd	0.1	1.7	nd	nd	nd
Caribou, meat	raw	2	nd	nd	nd	tr	0.2(0.03)	0.1(0.04)	nd	nd	tr	nd	tr	tr	0.2(0.05)	nd	nd	nd
Clams	raw	1	nd	nd	nd	0.1	0.3	0.1	tr	nd	tr	nd	nd	0.3	0.2	0.1	tr	nd
Cod, flesh	raw	1	nd	nd	nd	tr	0.1	tr	nd	nd	tr	nd	tr	tr	0.1	tr	nd	tr
Dall sheep, meat	raw	1	nd	nd	nd	tr	0.2	0.6	tr	tr	tr	nd	tr	tr	0.4	tr	nd	nd

Table 1a. continued

Table 1a. New data of saturated and monounsaturated fatty acid composition of several Arctic foods, listed alphabetically

Food Sample			Saturated Fatty Acids (g per 100 g)									Monounsaturated Fatty Acids (g per 100 g)						
Species and part	Preparation[1]	n	8:0	10:0	12:0	14:0	16:0	18:0	20:0	22:0	24:0	12:1	14:1	16:1	18:1	20:1	22:1	24:1
Deer, meat	raw	1	nd	tr	tr	0.2	1.1	0.8	tr	nd	tr	nd	tr	0.1	1.2	nd	nd	nd
Gopher, meat	raw	1	nd	nd	nd	tr	0.4	0.2	nd	nd	nd	nd	tr	0.1	0.8	tr	tr	nd
Grayling, flesh	raw	1	nd	nd	tr	tr	0.3	0.1	nd	nd	tr	nd	nd	0.1	0.4	tr	nd	nd
Grouse, meat	raw	2	nd	nd	tr	tr	0.1(0.08)	0.1(0.02)	tr	tr	nd	nd	tr	tr	0.1(0.12)	tr	nd	nd
Halibut, flesh	raw	1	nd	nd	nd	tr	0.2	0.1	nd	nd	nd	nd	tr	0.1	0.3	0.1	tr	nd
Harp seal, meat	boiled	1	nd	nd	nd	0.2	0.5	0.1	nd	nd	nd	nd	nd	0.6	0.8	1.0	0.1	nd
Herring, flesh	raw	1	nd	nd	tr	0.7	1.3	0.3	tr	tr	tr	nd	tr	0.4	0.8	0.1	tr	0.1
Longn.[6] sucker, flesh	boiled	1	nd	nd	nd	tr	0.1	tr	nd	nd	tr	nd	tr	tr	0.1	nd	nd	tr
Lynx, liver	raw	1	nd	nd	nd	tr	0.5	0.8	tr	tr	tr	tr	tr	tr	0.3	tr	nd	nd
Lynx, meat	raw	1	nd	tr	tr	tr	0.1	0.1	tr	nd	tr	nd	tr	tr	0.1	tr	nd	nd
Moose, fat	raw	2	tr	tr	tr	0.7(0.46)	13.2(2.67)	nd	0.5(0.20)	0.1(0.05)	0.1(0.05)	nd	tr	0.6(0.11)	52.8(3.66)	0.5(0.03)	tr	nd
Moose, liver	raw	1	nd	nd	nd	tr	0.2	0.3	tr	nd	nd	nd	tr	tr	0.2	tr	nd	nd
Ooligan, flesh	boiled	1	nd	nd	tr	2.5	5.3	1.1	tr	nd	tr	nd	0.1	2.0	2.3	0.6	0.1	0.3
Pike, flesh	cooked	1	nd	nd	nd	tr	0.2	0.1	nd	nd	nd	nd	nd	0.1	0.2	tr	nd	nd
Pike, flesh	raw	1	nd	nd	nd	tr	0.1	tr	nd	nd	tr	nd	tr	tr	0.1	nd	nd	nd
Porcupine, meat	boiled	1	tr	nd	tr	tr	0.6	0.3	nd	nd	tr	nd	tr	0.1	0.8	tr	tr	nd
Rabbit, liver	cooked	1	tr	nd	tr	tr	0.5	0.4	tr	tr	nd	nd	tr	tr	0.2	tr	tr	nd
Rabbit, meat	raw	1	tr	tr	tr	tr	0.4	0.1	nd	tr	tr	nd	tr	tr	0.2	tr	tr	nd
Sculpin, flesh	raw		nd	nd	nd	tr	0.2	tr	nd	nd	tr	nd	nd	0.2	0.2	0.2	tr	nd
Salmon, eggs	raw	2	nd	nd	tr	0.4(0.06)	1.5(0.00)	0.4(0.00)	nd	nd	nd	nd	tr	1.3(0.17)	3.8(0.026)	0.2(0.06)	tr	nd
Salmon, flesh	cooked	2	nd	nd	tr	0.2(0.06)	0.6(0.07)	0.2(0.01)	tr	tr	tr	nd	tr	0.3(0.14)	1.4(0.08)	0.6(0.08)	0.1(0.08)	tr
Salmon, flesh	raw	3	nd	nd	tr	0.1(0.04)	0.3(0.16)	0.1(0.04)	tr	tr	tr	nd	tr	0.1(0.08)	0.7(0.47)	0.3(0.22)	tr	tr
Salmon, flesh	smoked	3	nd	nd	tr	0.3(0.14)	1.2(0.47)	0.3(0.16)	tr	nd	tr	nd	tr	0.5(0.30)	2.2(1.40)	1.3(0.73)	0.1(0.04)	0.1(0.03)
Squirrel, meat	raw	1	nd	nd	tr	tr	0.1	0.1	tr	nd	nd	nd	tr	tr	0.1	tr	tr	nd
Trout, flesh	raw	2	nd	tr	tr	0.2(0.28)	0.6(0.71)	0.1(0.15)	tr	tr	tr	nd	tr	0.3(0.39)	0.9(1.1)	tr	tr	nd
Whitefish, flesh	raw	4	nd	tr	tr	0.1(0.04)	0.6(0.05)	0.1(0.03)	tr	nd	tr	tr	tr	0.4(0.11)	0.7(0.08)	tr	tr	tr

[1] Preparation. [2] Not detected. [3] Trace amounts < 0.05 g·100 g^{-1}. [4] Amniotic sac; [5] Mean (standard deviation); [6] Longnose

Table 1b. New data of omega-3 and omega-6 polyunsaturated fatty acid composition of several Arctic foods, listed alphabetically

Food Sample			Omega-3 Polyunsaturated Fatty Acids (g per 100 g)					Omega-6 Polyunsaturated Fatty Acids						
Species and part	preparation[1]	n	18:3n3	20:3n3	20:5n3	22:3n3	22:6n3	18:2n6	18:3n6	20:2n6	20:3n6	20:4n6	22:2n6	22:4n6
Bearded seal, meat	boiled	1	nd[2]	nd	0.1	nd	0.1	0.1	nd	nd	nd	0.1	nd	nd
Beluga, muktuk	boiled	1	nd	nd	0.5	nd	0.7	0.1	0.1	nd	nd	0.1	nd	nd
Black duck, liver	raw	1	nd	tr[3]	0.1	nd	0.1	0.1	tr	tr	nd	0.2	nd	tr
Caribou, fetus (a.s.)[4]	raw	1	tr	tr	tr	tr	tr	0.1	tr	tr	nd	0.1	nd	tr
Caribou, kidney	raw	2	tr	tr	tr	tr	nd	0.4(0.20)[5]	tr	tr	tr	0.2	nd	nd
Caribou, liver	raw	1	tr	tr	tr	tr	tr	0.2	tr	tr	tr	0.2	nd	nd
Caribou, meat	cooked	1	nd	nd	0.1	nd	nd	0.6	0.2	nd	nd	0.3	nd	nd
Caribou, meat	raw	2	nd	tr	tr	tr	nd	0.1(0.02)	tr	nd	nd	0.1(0.01)	nd	nd
Clams	raw	1	nd	nd	0.4	nd	0.2	tr	tr	tr	nd	tr	nd	nd
Cod, flesh	raw	1	tr	tr	0.1	tr	0.2	tr	tr	tr	tr	tr	nd	tr
Dall sheep, meat	raw	1	tr	tr	tr	tr	tr	0.2	0.1	tr	tr	0.1	nd	nd
Deer, meat	raw	1	tr	tr	tr	nd	nd	0.3	0.1	nd	nd	0.1	nd	nd
Gopher, meat	raw	1	tr	nd	nd	nd	nd	0.3	tr	nd	tr	tr	nd	nd
Grayling, flesh	raw	1	tr	nd	0.1	nd	0.1	0.2	0.1	tr	nd	tr	nd	nd
Grouse, meat	raw	2	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	nd	nd
Halibut, flesh	raw	1	nd	nd	0.1	nd	0.1	tr	tr	nd	nd	tr	nd	nd
Harp seal, meat	boiled	1	nd	nd	tr	nd	0.1	nd	nd	nd	nd	nd	nd	nd
Herring, flesh	raw	1	nd	nd	0.1	nd	0.3	0.1	tr	tr	nd	tr	nd	tr
Longn.[6] sucker, flesh	boiled	1	nd	nd	tr	tr	0.3	tr	tr	tr	nd	tr	nd	tr
Lynx, liver	raw	1	tr	tr	tr	tr	0.1	0.3	0.1	tr	tr	0.5	nd	nd
Lynx, meat	raw	1	tr	tr	tr	tr	tr	0.1	tr	tr	tr	0.1	nd	nd
Moose, fat	raw	2	0.3(0.09)	0.1(0.03)	tr	nd	tr	1.9(0.66)	1.5(0.59)	0.1(0.00)	0.1(0.00)	tr	tr	nd
Moose, liver	raw	1	tr	tr	tr	tr	tr	0.1	0.1	tr	tr	0.1	nd	nd
Ooligan, flesh	boiled	1	nd	nd	0.2	nd	0.5	0.2	tr	nd	nd	0.1	nd	nd
Pike, flesh	cooked	1	tr	nd	0.1	nd	0.1	tr	tr	nd	nd	0.1	nd	nd
Pike, flesh	raw	1	nd	nd	tr	tr	0.2	tr	tr	nd	nd	tr	nd	tr
Porcupine, meat	boiled	1	nd	nd	tr	nd	nd	0.3	0.4	nd	tr	tr	nd	nd

Table 1b. continued

Table 1b. New data of omega-3 and omega-6 polyunsaturated fatty acid composition of several Arctic foods, listed alphabetically

Food Sample			Omega-3 Polyunsaturated Fatty Acids (g per 100 g)					Omega-6 Polyunsaturated Fatty Acids						
Species and part	preparation[1]	n	18:3n3	20:3n3	20:5n3	22:3n3	22:6n3	18:2n6	18:3n6	20:2n6	20:3n6	20:4n6	22:2n6	22:4n6
Rabbit, liver	cooked	1	tr	tr	tr	nd	nd	0.2	0.1	tr	tr	tr	tr	nd
Rabbit, meat	raw	1	tr	tr	tr	nd	nd	0.2	tr	tr	tr	tr	nd	nd
Salmon, eggs	raw	2	tr	tr	1.1(0.14)	nd	1.3(0.18)	0.1(0.01)	tr	tr	tr	0.1(0.00)	nd	nd
Salmon, flesh	cooked	2	tr	tr	0.5(0.05)	tr	0.8(0.13)	0.2(0.15)	0.1(0.08)	tr	tr	tr	tr	tr
Salmon, flesh	raw	3	tr	tr	0.2(0.08)	tr	0.3(0.16)	tr	tr	tr	tr	tr	tr	tr
Salmon, flesh	smoked	3	tr	tr	0.5(0.09)	nd	1.0(0.26)	0.1(0.04)	tr	tr	tr	0.1(0.01)	tr	tr
Sculpin, flesh	raw	1	nd	nd	0.2	nd	0.2	tr	nd	nd	nd	tr	nd	nd
Squirrel, meat	raw	1	tr	tr	tr	nd	0.1	0.2	tr	tr	tr	tr	nd	nd
Trout, flesh	raw	2	tr	tr	0.2(0.17)	tr	0.6(0.65)	0.1(0.14)	0.1(0.13)	tr	tr	0.1(0.06)	tr	tr
Whitefish, flesh	raw	4	tr	tr	0.2(0.05)	tr	0.3(0.03)	0.2(0.11)	0.1(0.03)	tr	tr	0.1(0.03)	tr	tr

[1] Preparation; [2] Not detected; [3] Trace amounts < 0.05 g·100 g^{-1}; [4] Amniotic sac; [5] Mean (standard deviation); [6] Longnose

Table 2. New data for vitamin D in traditional Arctic foods, listed alphabetically

Food sample			Mean
Species and part	Preparation	n	Vitamin D µg·100 g^{-1}
Arctic char, flesh	raw	4	25.78
Bearded seal, flesh	boiled	1	1.78
Beluga, blubber	boiled	1	13.32
Beluga, blubber	raw	2	0.35
Beluga, mattak/skin	boiled	1	1.31
Beluga, mattak/skin[1]	raw	1	1.80
Beluga, oil	aged	1	26.68
Burbot, eggs	raw	2	15.23
Burbot, liver	raw	2	318
Caribou, bone grease	boiled	1	0.00
Caribou, bone marrow	aged	2	0.00
Caribou, bone marrow	raw	3	0.02
Caribou, brain	roasted	2	0.00
Caribou, kidney	raw	3	0.84
Caribou, liver	raw	4	1.12
Caribou, meat	raw	2	0.00
Cisco, eggs	raw	2	6.49
Grizzly bear, grease	boiled	1	0.00
Lake trout, flesh	raw	3	19.70
Moose, liver	raw	1	0.00
Muskox, fat[1]	raw	2	2.79
Narwhal, blubber	raw	1	9.95
Narwhal, mattak/skin	raw	1	0.00
Narwhal, oil	aged	1	3.96
Polar bear, meat	raw	1	0.00
Ringed seal, blubber	raw	1	1.55
Ringed seal, brain	raw	2	1.14
Ringed seal, eyes	raw	2	2.58
Ringed seal, liver	raw	3	18.07
Ringed seal, meat	raw	3	0.03
Sculpin, meat and bones	boiled	1	2.02
Sculpin, meat and bones	raw	1	14.11
Walrus, blubber	aged	2	0.00
Walrus, blubber	raw	4	0.23
Walrus, liver	raw	1	0.00
Walrus, meat	raw	1	0.00
Whitefish, flesh	raw	2	3.50

[1] One sample was a composite from two or more individual animals; equal portions per animal were sampled.

Table 3. New data for proximate composition of selected traditional Arctic foods, listed alphabetically

Food Sample			Proximate Composition and Energy Values per 100 g					
			Moisture	Crude Fat	Protein	Ash	Carbohydrates[1]	Energy[1]
Species and part	Preparation	n	(g)	(g)	(g)	(g)	(g)	(kcal)
Caribou, bone grease	boiled	1	40.0	59.0	0.10	0.03	0.88	535
Caribou, brain	roasted	2	57(8.2)[2]	19(1.4)	20(6.6)	3(1.1)	1(1.3)	256(44)
Grizzly bear, grease	boiled	1	41.6	57.0	0.12	0.00	1.28	518
Moose, liver	raw	1	71.7	1.12	21.4	1.32	4.49	114
Walrus, liver	raw	4	74(1.4)	1.3(0.41)	18(1.6)	1.1(0.16)	6(3.0)	105(5)
White winged scoter, meat	raw	1	70.1	5.35	22.1	1.27	1.18	141

[1] Calculated value

[2] Mean (standard deviation)

Table 4a. New data for mineral composition of selected Arctic traditional foods, listed alphabetically

Food Sample			Mineral Concentration per 100 g				
			Ca	Fe	Cu	Zn	Mg
Species and part	Preparation	n	(mg)	(mg)	(mg)	(mg)	(mg)
Arctic char, flesh	raw	5	10(6.4)[1]	0.3(0.10)	0.1(0.07)	0.5(0.07)	27(0.8)
Arctic char, skin	raw	3	39(19)	0.5(0.21)	0.1(0.04)	1.7(0.33)	17(2.0)
Caribou, bone grease	boiled	1	1.89	0.79	nd[2]	0.40	0.20
Caribou, bone marrow	aged	2	21(10)	2(1.5)	tr[3]	0.2(0.02)	2(1.1)
Caribou, bone marrow	raw	4	32(33)	1.2(0.40)	nd	0.2(0.06)	1.5(0.82)
Caribou, brain	roasted	2	43(37)	7(2.5)	0.3(0.19)	1.9(0.27)	17(1.3)
Caribou, flesh	raw	5	3.8(0.50)	4.2(0.75)	0.5(0.30)	3(1.1)	27(1.2)
Grizzly bear, grease	boiled	1	0.40	0.13	0.00	0.42	0.16
Lake trout, flesh	raw	4	79(114)	0.4(0.14)	0.01(0.02)	0.6(0.17)	26(4.1)
Moose, liver	raw	1	5.53	11.12	0.83	2.61	16.37
Polar bear, meat	raw	1	3.46	4.98	0.10	7.21	20.69
Ringed seal, meat	raw	3	1.6(0.90)	10(16)	0.2(0.18)	0.9(1.1)	10(15)
Ringed seal, liver	raw	2	4.6(0.81)	101(72)	1.1(0.53)	4.1(0.86)	21(0.1)
Spruce	dried	1	17.74	5.06	0.21	4.27	4.29
Walrus, blubber	raw	4	3.1(0.87)	0.7(0.30)	0.3(0.24)	0.4(0.13)	2.3(0.81)
Walrus, meat	aged	1	4.64	16.35	0.07	4.70	19.79
Walrus, meat	raw	2	6(2.1)	16(3.3)	0.1(0.02)	5.0(0.30)	19(2.2)
Walrus, flipper	aged	1	13.28	1.77	0.03	0.65	9.54
Walrus, liver	raw	4	4.0(0.74)	32(10)	3(1.5)	6(2.0)	18(1.9)
Whitefish, flesh	dried	1	65.16	1.21	0.24	1.29	78.27
White-winged scoter,meat	raw	1	4.59	11.64	0.79	1.67	28.31

[1] Mean (standard deviation)

[2] Not detected

[3] Trace amounts $< 0.005\ mg \cdot 100\ g^{-1}$

Table 4b. New data for mineral composition of selected Arctic traditional foods, listed alphabetically

Food Sample			Mineral Concentration per 100 g				
			Na	K	P	Mn	Se
Species and part	Preparation	n	(mg)	(mg)	(mg)	(mg)	(mg)
Arctic char, flesh	raw	5	45(11)[1]	144(7)	211(11)	0.01(0.01)	0.01(0.01)
Arctic char, skin	raw	3	48(10)	126(4)	182(9)	0.01(0.00)	0.02(0.07)
Caribou, bone grease	boiled	1	6.89	0.48	1.22	nd[2]	na[3]
Caribou, bone marrow	aged	2	51(13)	24(12)	27(4.6)	0.01(0.00)	tr[4]
Caribou, bone marrow	raw	4	32(10)	9(3.9)	26(21)	tr	tr
Caribou, brain	roasted	2	129(7)	123(5)	430(62)	0.04(0.00)	na
Caribou, flesh	raw	5	47(9.9)	141(8)	202(12)	0.03(0.01)	0.01(0.00)
Grizzly bear, grease	boiled	1	3.90	1.27	3.10	nd	na
Lake trout, flesh	raw	4	43(9.7)	145(14)	250(84)	0.01(0.01)	0.03(0.01)
Moose, liver	raw	1	85.34	139	272	0.35	na
Polar bear, meat	raw	1	122	157	165	0.04	0.03
Ringed seal, meat	raw	3	22(13)	59(74)	86(115)	0.01(0.01)	0.01(0.04)
Ringed seal, liver	raw	2	83(6.7)	152(5)	267(1)	0.36(0.02)	0.16(0.15)
Spruce	dried	1	25.52	27.09	6.10	0.20	na
Walrus, blubber	raw	4	52(16)	34(15)	28(9.8)	tr	0.02(0.00)
Walrus, meat	aged	1	67.12	142	157	0.01	0.14
Walrus, meat	raw	2	66(2.3)	119(1)	145(16)	0.02(0.00)	0.07(0.02)
Walrus, flipper	aged	1	158	83.99	54.21	0.06	0.03
Walrus, liver	raw	4	100(20)	121(23)	213(33)	0.28(0.09)	0.25(0.07)
Whitefish, flesh	dried	1	137.53	509.07	728.82	0.15	na
White-winged scoter, meat	raw	1	71.90	147.88	232.83	0.06	na

[1] Mean (standard deviation)

[2] Not detected

[3] Not analyzed

[4] Trace amounts < 0.005 mg·100 g^{-1}

These important sources of nutrients are receiving new attention from many international, national and regional agencies and governments. Traditional/country food resources of Arctic peoples have a significant place in this knowledge because of the excellent sources of nutrients contained in food systems primarily comprised of animal food species.

For health education networks in the Arctic, it is necessary to recognize these sources of nutrients in order to conduct meaningful education and counseling activities, and to enhance the health promotion agenda.

Expected Project Completion Date

This work on nutrient benefits in Arctic traditional/country foods is ongoing.

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Follow-Up of Preschool Age Children Exposed to PCBs and Mercury through Fish and Marine Mammal Consumption

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Abstract

Two data collection trips were conducted during the year 2000-2001 and enabled testing a total of 59 children. There are no results to present at this stage in relation to the study objectives. Nevertheless, data are available to describe the participation rate, socio-demographic characteristics of the sample, country food consumption, prenatal and current exposure to polychlorinated biphenyls and mercury. We are confident that the next field trips, planned for year 2001-2002 will enable testing another 50 children and that the sample size of 100 children will be reached.

Key Project Messages

1. Two data collection trips were conducted during the year 2000-2001 and enabled testing a total of 59 children.
2. There are no results to present at this stage in relation to the study objectives. Data are available

to describe the participation rate, socio-demographic characteristics of the sample, country food consumption, prenatal and contemporaneous exposure to polychlorinated biphenyls (PCBs) and (mercury) Hg.

Objective

- To examine the neurophysiological and neurological long-term consequences of prenatal exposure to PCBs and methylmercury (MeHg).

Introduction

The effects of prenatal exposure to PCBs and MeHg resulting from fish consumption have been studied in fish eating populations from various countries. Prenatal exposure to PCBs have been linked to deficits in neurobehavioral development during infancy in three studies (Darvill et al. In press, Gladen et al. 1988, Jacobson et al. 1985, Jacobson et al. 1992, Rogan and Gladen 1991). Only one study looked at neurobehavioural effects of prenatal MeHg exposure during infancy and no effects were found (Davidson et al. 1995, Davidson et al. 1998, Myers et al. 1995). Two PCB and two MeHg studies provided data for school age children (Crump et al. 1998, Jacobson et al. 1990, Jacobson and Jacobson 1996, Grandjean et al. 1997, Patandin et al. 1999), however, neuromotor as well as neurophysiological effects were poorly documented. Although neurophysiological testing was performed in one of these studies with school aged children exposed to MeHg, the study remained incomplete. Furthermore, no study has been aimed at investigating cognitive deficits under MeHg exposure using event-related potentials.

The purpose of this research is to examine the long-term consequences of prenatal exposure to PCBs and MeHg. This project is designed to extend previous findings by studying domains of effects that have been overlooked in most of the previous studies (neurophysiological and neurological endpoints) that could be related to learning difficulties and disabilities. The large number of highly exposed Aboriginal children in Northern Quebec provides a unique opportunity to:

1. study the impact of PCBs and MeHg on child development;
2. provide the information required for the development of blood guidelines, no effect thresholds, acceptable daily intakes, and health advisories for Canadian children and women of reproductive age; and
3. broaden our knowledge on the nature of specific deficits associated with the exposure to these environmental contaminants.

The sample will comprise 100 Nunavik Inuit children between 5 and 6 years of age. According to in utero PCBs and MeHg exposure levels (low and high), two subsets of 50 children will be formed. Prenatal exposure to PCBs and MeHg was documented from cord blood analysis at birth. Groups will be comparable regarding the socio-economic status. A neurological exam will be performed, the fine and gross neuromotor function as well as the visual system and the cognitive and attentional functions will be assessed. Demographic, socio-familial and biological potential confounders will be assessed via maternal interviews and blood sample analysis.

Activities in 2000-2001

Two data collection trips were planned for the year 2000-2001. These two trips were conducted and enabled the testing of 59 children.

Results and Discussion

There are no results to present at this stage in relation to the study objectives. Nevertheless, data are available to describe the participation rate, socio-demographic characteristics of the sample, country food consumption, and prenatal and current exposure to PCBs and Hg.

Participation rates and sample characteristics

Inuit women from Northern Quebec (Nunavik) were invited to participate in this study. This study is the continuation of the Cord Blood Monitoring Program in which they had participated at the birth of their child. The Nunavik region is located north of the 55th parallel; 7660 Inuit are scattered along a 2000-km seashore line along Hudson Bay, Hudson Strait and Ungava Bay – about 1500 km from Montreal and 2000 km from the Great Lakes. The Nunavik Inuit live in 14 villages, ranging from 125 to 1300 inhabitants per village. Among the eligible women, 7.5% were excluded because they were outside of the targeted villages and 37.5% were unreachable. Among the women invited to participate in this study, 76.0% agreed to participate. Only two women did not complete the interview, and it was not possible to test two children. The study participants from Puvirnituk (12), Akulivik (1) and Ivujivik (1) were met by research assistants in the Inuulitsivik Health Center in Puvurnituk. Participants from the village of Inukjjuak (13) were met in the nursing station of that village, while participants from Kuujjuak (16), Kangiqsualujuak (7), Kangirsuk (3), Quaqtak (2), Tasujiak (1), Kangiqsujuak (1) and Aupaluk (1) were met in Kuujjuak. Socio-demographic and personal characteristics were documented from interviews conducted by a highly experienced research assistant and are summarized in Table 1.

A large proportion of women were married or living with someone. Among the women interviewed, 75.9% lived or have lived with the father of the child involved in the study. Only 5.2% of the participating women were primiparous, and 82.8% had already delivered four or more children. High-school diplomas had been obtained by 29.3% of participants. The interview was done with an interpreter in 13.8% of the cases.

Since a primary route of exposure to environmental contaminants in the Inuit population is the consumption of traditional food, especially fish and marine mammals, for descriptive purposes, we documented the frequency of traditional food consumption during the child's previous year of life (Table 2). The participants were questioned about their consumption of the following fish species: Arctic char, lake trout, salmon and white fish. Their consumption of beluga, seal, narwhal, whale, walrus and marine bird eggs was also evaluated. Fish, beluga, seal

Table 1. Characteristics of participants

	Total N	Mean	SD[1]	Range	n	%
Marital status (% not single)	58				47	81
Child's age (years)	57	5.5	0.4	4.8 - 6.2		
Mother's age (years)	57	30.4	5.4	21.4 - 45.1		
Education (grade)	58	9.2	2.3	5.0 - 15.0		
Employment status (% employed)	58				41	70.7
Socioeconomic status[2]	40					
Unskilled labourers					5	12.5
Semi-skilled workers					8	20
Skilled craftsmen, clerical and sales					16	40
Technical, small business					8	20
Managers and minor professionals					3	7.5
Language of interview	58					
English					49	84.5
French					1	1.7
Inuktitut					8	13.8
Parity (# children)	58	4.2	2.1	0 - 8.0		
Breast-feeding status (% breastfed)	57				41	71.9

[1] Standard deviation

[2] Hollingshead index (Hollingshed 1975) for the mothers who had been working during the previous year

Table 2. Traditional/country food consumption during pregnancy (n = 58)

	Meals/week			At least 1 meal/week (%)	At least 1 meal/month (%)
	Mean	Standard deviation	Range		
Fish meals	4.4	5.6	0.0 - 21.0	65.5	93.1
Beluga meals					
Beluga fat	0.5	1.6	0.0 - 7.0	12.1	26
Beluga muktuk	0.2	0.3	0.0 - 1.7	5.2	17.2
Beluga meat	0	0.1	0.0 - 0.4	0	1.7
Beluga liver	0	0	0.0 - 0.1	0	0
Seal meals					
Seal fat	0.7	1.7	0.0 - 7.0	20.7	34.5
Seal meat	0.1	0.2	0.0 - 0.7	0	20.7
Seal liver	0.1	0.2	0.0 - 1.0	0	12.1
Eggs (n = 34)	0.1	0.2	0.0 - 0.6	0	20.6

and eggs were the most frequently consumed species whereas the consumption of narwhal and walrus was much less common in the selected communities.

Exposure data

A blood sample was obtained from each participating child. One 5-mm diameter hair sample was also collected from the child. PCB congener and chlorinated pesticide concentrations were measured at birth in cord plasma and in the child's plasma collected at the testing session. Hg concentrations were determined in cord and the child's whole blood as well as in the hair sample collected at testing time. Organochlorine, heavy metals and selenium analyses were performed at the laboratory of the *Centre de Toxicologie du Québec*, which is accredited by the Canadian Association for Environmental Analytical Laboratories. Blood samples containing EDTA as the anticoagulant were centrifuged and the plasma was collected in glass vials pre-washed with hexane. Plasma samples were stored at −20°C until time of analysis. A 1:1:3 mixture of ammonium sulfate/ethanol/hexane was first added to the plasma to extract PCB congeners. The extracts were then concentrated and purified on two Florisil columns. The 14 most prevalent PCB congeners (IUPAC nos. 28, 52, 99, 101, 105, 118, 128, 138, 153, 156, 170, 180, 183, 187) and 11 chlorinated pesticides or their metabolites (aldrin, α-chlordane, γ-chlordane, *p,p'*-DDT, *p,p'*-DDE, HCB, β-HCH, mirex, *cis*-nonachlor, *trans*-nonachlor, oxychlordane) were measured in the purified extracts by high-resolution gas chromatography using two capillary columns (Hewlett-Packard Ultra I and Ultra II) and dual Ni-63 electron capture detectors. Quality control procedures were described previously (Rhainds et al. 1999).

Percent recovery varied from 89% to 100% and the detection limit was approximately 0.02 $\mu g \cdot L^{-1}$ for all compounds. Coefficients of variation (n = 20, different days) ranged from 2.1% to 9.1% and biases from −10.9% to 3.8%. Since organochlorines distribute mainly in body fat, concentrations in plasma samples are reported in $\mu g \cdot kg^{-1}$ of lipids. Total cholesterol, free cholesterol and triglycerides were measured in plasma samples by standard enzymatic procedures, while phospholipids were determined according to the enzymatic method of Takayama et al. (1977), using a commercial kit (Wako Pure Chemical Industries, Richmond VA). The concentration of total plasma lipids was estimated according to the formula developed by Phillips et al. (1989). Total Hg concentrations were determined in samples of whole cord and child blood and child hair by cold vapour atomic absorption spectrometry. Samples were digested with nitric acid, reduction of Hg was accomplished using anhydrous stannous chloride ($SnCl_2$) and the reaction was catalyzed with cadmium chloride ($CdCl_2$). Metallic Hg was volatilized and detected by atomic absorption spectrometry (Pharmacia Model 120). The detection limit for blood Hg analysis was 1.0 $nmol \cdot L^{-1}$. Quality control procedures were described previously (Rhainds et al. 1999). Coefficients of variation (n = 50, different days) at levels of 40 and 90 $nmol \cdot L^{-1}$ (in-house reference materials) were 5% and 5.5%, respectively. Relative biases were 2.4% and −0.4%, respectively. The detection limit for hair Hg analysis was 1 $nmol \cdot g^{-1}$. Accuracy and precision data were obtained using certified reference material through Health Canada's hair Hg interlaboratory comparison program. The coefficients of variation (n = 50, different days) at levels of 12.3 $\mu g \cdot g^{-1}$ (Bureau of Community Reference) and 4.42 $\mu g \cdot g^{-1}$ (National Institute for Environmental Studies) were 4.8% and 4.3%, respectively. The relative biases were −2.2% and +1.9%, respectively.

Descriptive statistics of Hg and PCB concentrations obtained in cord and child blood and Hg concentrations in child hair are presented in Table 3. The average Hg concentration is 1.7 times higher in cord blood than child blood. The correlation between child blood and child hair Hg concentrations is very high ($r = 0.88$, $p \leq .000$, n = 58), suggesting that both provide reliable assessments of current Hg exposure. PCB congener 153, the most prevalent congener, was used as a marker variable to reflect

Table 3. PCB and Hg concentrations obtained at birth and at 5 years of age

		Arithmetic		Geometric			
	n	mean	SD[1]	Mean	SD	Range	Interquartile range
Hg							
Cord blood ($nmol \cdot L^{-1}$)	59	109.1	76.09	82.75	2.23	9.0 - 316.0	43.0 - 165.0
5-year blood ($nmol \cdot L^{-1}$)	58	63.66	49.44	43.83	2.62	4.0 - 191.0	20.5 - 91.5
5-year hair ($\mu g \cdot g^{-1}$)	59	2.91	2.08	2.19	2.24	0.3 - 8.6	1.2 - 4.1
PCB Congener 153							
Cord blood ($\mu g \cdot kg^{-1}$ lipids)	59	118.41	73.05	98.94	1.86	21.6 - 405.3	63.8 - 145.3
5-year blood ($\mu g \cdot kg^{-1}$ lipids)	58	155.20	227.81	78.08	3.26	10.2 - 1467.2	25.9 - 192.9

[1] Standard deviation

exposure to the moderate to heavily chlorinated PCB congeners. The average ratio of cord to child blood is 0.8.

Hg concentrations reported in other cohorts are presented in Table 4. The data confirmed that prenatal exposure to Hg among the Inuit of Northern Quebec is higher than that observed in the general population sample in southern Quebec. When compared with the Faroe Islands cohort which has been studied for electrophysiological effects associated with Hg exposure, the Nunavik Inuit Hg range of exposure – for cord blood, child blood and child hair – is very similar. Because the correlation between prenatal Hg and organochlorine exposure is lower in the Nunavik cohort ($r = 0.29$, $p \leq .05$, $n = 59$), it should be easier to identify the specific deficits attributable to each of these environmental contaminants.

With regard to PCB exposure, it is difficult to compare the data in the present study with those from the first PCB neurobehavioural studies conducted in Michigan (Jacobson and Jacobson 1996) and North Carolina (Rogan et al. 1986), which were based on packed columns gas chromatography technology for organochlorine determination.

In Table 5, PCB concentrations observed in the present sample are compared with those from the general Canadian and American populations, and with other cohorts studies using similar analytical methods for PCBs determination (congener specific analysis). For each comparison, the Nunavik PCB concentrations were calculated according to the method used in the comparison study. Comparison of cord blood PCB levels confirmed that prenatal exposure to PCBs among Nunavik Inuit is much higher than that observed in general populations from southern Quebec and New Bedford, Massachusetts, USA. The Nunavik PCB concentrations are similar to those found in cord blood samples of the Netherlands study, and they are about two times lower than those found in the groups of marine mammal consumers from the Faroe Islands and Greenland cohorts.

Conclusions

Two data collection trips were conducted during the year 2000-2001 and enabled testing a total of 59 children. The activities to be achieved in the next year have not changed; these are to test another 50 children which will end the data collection phase. No results have been published or communicated to date. Because of the nature of this research, no results will be available for publication before the end of the data collection.

Expected Project Completion Date

March 31, 2002

Table 4. Comparison of Hg concentrations in blood ($\mu g \cdot L^{-1}$) and hair ($\mu g \cdot g^{-1}$)

Cohort	Medium	Years	n	Geometric Mean	Range	Interquartile Mean
Nunavik Inuit	Cord blood[1]	1993-1996	475	14.2	1.0 - 104.0	8.4-24.8
	5-year blood[2]	2000	58	8.8	0.8 - 38.2	4.1-18.3
	5-year hair[2]	2000	58	2.2	0.3 - 8.6	1.2-4.1
Southern Quebec[3]	Cord blood	1993-1995	1108	1.0	0.9 - 1.0[4]	
Faroe Islands[5]	Cord blood	1986-1987	894	22.9	13.4 - 41.3	
	Child's hair at 7 years	1993-1994	903	3.0	1.7 - 6.1	
	Child's blood at 7 years	1993-1994	672	8.8	4.8-18.2	

[1] Source: Dewailly et al. 1998

[2] Source: Current study

[3] Source: Rhainds et al. 1999

[4] 95% confidence interval

[5] Source: Grandjean et al. 1999

Table 5. Comparison of PCB concentrations observed in Nunavik cord blood samples ($\mu g \cdot L^{-1}$) with those in comparison groups and high-level cohorts using the same analytical methods

		PCB	Arithmetic		
	Years	**n**	**Congener**	**Mean**	**Range**
Canada, Nunavik Inuit[1]	1993-1996	59	Aro 1260[2]	2.7	0.5 - 8.4
		59	153	0.3	0.5 - 1.0
		59	ΣPCB[3]	1.3	0.2 - 4.2
Canada, southern Quebec[4]	1993-1995	656	Aro 1260[2]	0.55	0.5 - 0.566
USA, New Bedford[7]	1993-1998	751	153	0.1	0.0 - 1.3
Netherlands[8]	1990-1992	382	153	0.2	0.0 - 0.9
Faroe Islands[9]	1994-1995	174	ΣPCB[3]	2.5	0.7 - 8.7
Greenland, Disco Bay[10]	1994-1996	160	Aro 1260[2]	4.2	not available

[1] Source: Current study

[2] Aroclor 1260, 5.2 times the sum of PCB congeners 138 and 153

[3] SPCB, 2 times the sum of PCB congeners 138, 153 and 180

[4] Source: Rhainds et al. 1999

[5] Geometric mean

[6] 95% Confidence interval

[7] Source: Korrick et al. 2000

[8] Source: Koopman-Esseboom et al. 1994

[9] Source: Steuerwald et al. 2000

[10] Source: Bjerregaard and Hansen 2000

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Transplacental Exposure to PCBs and Infant Development/Human Exposure Assessment

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Abstract

The objective of this study is to examine the consequences of in utero and lactational exposure to polychlorinated biphenyls on Inuit infants, from birth to 12 months of age. Of particular interest is the impact of exposure on newborn thyroid hormone levels and physical growth, on the infant's overall health, mental, psychomotor and neurobehavioural development, and on visual and spatial information processing abilities. The data collection of this ongoing study started in November 1995 and will end in 2002. The continuation of data collection was the main activity carried out in 2000-2001. The data collection in Greenland began in March 2000. To date, 244 Nunavik mothers have completed the prenatal interview and 204 have completed the postnatal interview; 168 infants were assessed at 6.5 months and 156 were assessed at 11 months of age. No preliminary results are available regarding the effects of exposure to polychlorinated biphenyls and effects analysis will wait until we get the final sample size of 300 11-month-old infants (200 from Nunavik, 100 from Greenland).

Key Project Messages

1. The data collection of this ongoing study started in November 1995 and will end in 2002. To date, 244

Nunavik mothers have completed the prenatal interview and 204 have completed the postnatal interview; 168 infants were assessed at 6.5 months and 156 were assessed at 11 months of age.

2. No preliminary results are available regarding the effects of exposure to polychlorinated biphenyls (PCBs) on infant health and development. Effects analysis will wait until we obtain the final sample size.
3. Analyses completed in the past year corroborated previous findings relating marine mammal and fish consumption to increased mercury (Hg) and selenium (Se) body burden. Despite widespread knowledge regarding the presence of these contaminants in traditional foods, a large proportion of Inuit women increased their consumption of these foods during pregnancy, due primarily to pregnancy-related changes in food preferences and the belief that these foods are beneficial during pregnancy.
4. Prenatal exposure to PCBs in the Nunavik cohort is similar to that reported in the Dutch cohort but much lower than those in other Arctic cohorts (Faroe Islands and Greenland). Prenatal exposure to Hg was similar to that found in the Faroe Islands cohort but lower than that documented in the Seychelles Islands and New Zealand cohorts.
5. Levels of N3 polyunsaturated fatty acids in plasma phospholipids and Se in blood are relatively high in the Nunavik cohort.
6. The moderate correlations observed between organochlorine (OC) and methylmercury (MeHg) concentrations in the Nunavik cohort will allow us to tease out the specific developmental deficits attributable to each toxin. Similarly, the weak correlations noted between environmental contaminants and nutrients will facilitate the documentation of possible protective effects afforded by either N3 polyunsaturated fatty acids or Se against neurotoxic contaminants.
7. PCB 153 plasma concentrations in 6-month-old infants were poorly predicted by maternal plasma concentrations alone. A model that included maternal PCB 153 plasma concentration, the duration of breast feeding and an estimate of the infant body fat mass provided a good prediction of PCB 153 plasma concentration at 6 months postpartum. Models developed in the present study may be used to reliably predict prenatal and postnatal exposure to PCBs in populations environmentally exposed to these compounds.

Objectives

1. To examine the consequences of in utero and lactational exposure to PCBs on Inuit infants from birth to 12 months of age. Of particular interest is the impact of PCBs and Hg exposure on newborn's thyroid hormones, physical growth, physical and central nervous system maturity, on infant's overall health, mental, psychomotor and neurobehavioral development, and on functional and neural impairment in the domains of visual and spatial information processing.
2. To document the exposure to heavy metals, OCs and polyunsaturated fatty acids (PUFAs) of newborns from selected communities in Nunavik. This ongoing effect study provides the opportunity to continue the cord blood monitoring program financed by the Northern Contaminants Program since 1993 and as a result, to be able to perform long-term time trend analysis of human exposure.

Introduction

Organochlorines are carried from industrialized countries to the Arctic by long-range atmospheric transport, waterways, and oceanic currents. Due to their high lipophilicity and resistance to biodegradation, OCs bioaccumulate in fatty tissues or organisms and are biomagnified through the food chain, resulting in relatively heavy concentrations in the fat of predator species. Because fish and marine mammals represent an important part of the diet of the Inuit, exposure to OCs are of particular interest for public health authorities in the Arctic regions. Elevated levels of PCBs and Hg in Inuit adults and newborns have been reported by Dewailly et al. (1994, 1998) for the Northern Quebec (Nunavik) Inuit while high PCB and Hg concentrations have recently been reported by Bjerregaard and Hansen (2000) for Greenlandic Inuit mothers and newborns.

The developmental toxicity of heat-degraded PCBs was first recognized in Japan in the late 1960s and in Taiwan in the late 1970s. Infants born to women who had consumed rice oil contaminated with mixtures of PCBs and polychlorinated dibenzofurans had skin rashes and exhibit poorer intellectual functioning during infancy and childhood (Chen et al. 1992, Yu et al. 1991). Effects of prenatal exposure to background levels of PCBs and other OCs from environmental sources have been studied since the 1980s in four major prospective longitudinal studies conducted in Michigan, North Carolina, the Netherlands and Oswego, New York. The source of PCB exposure was fish consumption from the Great Lakes in both the Michigan and the Oswego studies, and consumption of dairy products in the Netherlands. Newborns from the North Carolina cohort were exposed to background levels of OCs, and there was no specific source of exposure. PCBs exposure was associated with less optimal newborn behavioural function (e.g. reflexes, tonicity and activity levels) in all four studies (Jacobson et al. 1984, Stewart et al. 2000, Rogan et al. 1986, Huisman et al. 1995a). Adverse neurological effects of exposure to PCBs have been found up to 18 months of age in the Netherlands study (Huisman et al. 1995b). In Michigan and the Netherlands, higher cord serum PCBs concentrations were associated with lower birth weight and slower growth rate (Fein et al. 1984, Jacobson et al. 1990b, Patandin et al. 1998). One principal finding in Michigan was an association with poorer visual information processing ability during infancy, which indicated a deficit in visual memory or attention (Jacobson et al. 1985, 1990a, 1992). This effect was recently confirmed in the Oswego study at ages 6- and 12-months (Darvill et al. In press.). Although this association was not seen during infancy in the Netherlands study, PCB exposure has been linked to decreased attention and reaction time at preschool age in this study (Patandin et al. 1999). In North Carolina, deficits in psychomotor development up to 24 months were seen in the highest PCBs exposed children (Gladen et al. 1988, Rogan and Gladen 1991). Michigan and the Netherlands studies have linked PCB exposure to poorer intellectual function (Jacobson and Jacobson 1996, Patandin et al. 1999), specifically reduced intellectual quotient and deficits in reading and comprehension. All effects were related to prenatal exposure.

Activities in 2000-2001

The data collection for this effects study began in November 1995. The main focus of this year's activity has been data collection. One major accomplishment during the current year was the training of a maternal interviewer/infant tester for the Greenland portion of the study and the initiation of data collection in Greenland. Subject recruitment and infant and maternal assessments in Nunavik continued throughout this year. So far, the participation rate in the present study has been high and very few women have withdrawn their collaboration during the course of the study. The participation and retention rates are very positive: the initial participation rate was 74% and comparable to the 80% we had projected; only 0.9% refused to continue in the study after completing the prenatal interview. Between November 1995 and April 2001, 244 Nunavik mothers completed the prenatal interview and 204 completed the postnatal interview; 168 infants were assessed at 6.5 months of age and 156 were assessed at 11 months of age.

Results and Discussion

No preliminary results are available regarding the effects of exposure to PCBs on infant health and development. Effects analysis will wait until we obtain the final sample size of 300. Nevertheless, analyses of several related issues were completed in the past year and are summarized in the following abstracts prepared for conferences and publications during 2000-2001.

Determinants of Polychlorinated Biphenyls and Methylmercury Exposure in Inuit Women of Childbearing Age

This manuscript has been accepted for publication in *Environmental Health Perspectives*. These results were also presented to the Eleventh International Congress on Circumpolar Health, Harstad, Norway, June 2000.

Abstract

Objectives: To identify maternal characteristics associated with traditional food consumption and to examine food items associated with PCBs and Hg body burden in pregnant Inuit women from Northern Quebec. *Methods*: Women from three communities were interviewed in mid-pregnancy and at 1-month and 11-months postpartum. PCBs, Hg and Se were measured in maternal blood, and Hg in maternal hair. *Results*: The women reported eating significant amounts of fish, beluga muktuk/fat, seal meat and seal fat. Although fish and seal consumption was associated with lower socioeconomic status, beluga whale consumption was uniform across strata. Fish and seal meat consumption was associated with increased hair Hg concentrations. Pregnancy traditional food intake was unrelated to PCB body burden, which is more a function of lifetime consumption. *Conclusions*: This study corroborated previous findings relating marine mammal and fish consumption to increased Hg and Se body burden. Despite widespread knowledge regarding the presence of these contaminants in traditional foods, a large proportion of Inuit women increased their consumption of these foods during pregnancy, due primarily to pregnancy-related changes in food preferences and the belief that these foods are beneficial during pregnancy.

Prenatal Exposure of the Northern Quebec Inuit Infants to Environmental Contaminants

This manuscript was submitted to *Environmental Health Perspectives*.

Abstract

The Inuit population residing in Nunavik (Northern Quebec, Canada) relies heavily on species from the marine food-web for subsistence and is therefore exposed to high doses of environmental contaminants such as PCBs and MeHg, and to a lesser extent lead (Pb). In view of the neurotoxic properties of these substances, especially following developmental exposure, we initiated a study on infant development in this remote coastal population. Here we report the magnitude of prenatal exposure to these contaminants and to selective nutrients in Inuit mothers and their newborns who were recruited in three villages on the Hudson Bay coast. Interviews were conducted during pregnancy and at 1 and 11 months postpartum and biological samples were collected for Hg, Pb and OC analyses as well as Se and N-3 PUFA. Prenatal exposure to Hg was similar to that found in the Faroe Islands cohort but lower than that documented in the Seychelles Islands and New Zealand cohorts. Prenatal exposure to PCBs in the Nunavik cohort is similar to that reported in the Dutch cohort but much lower than those in other Arctic cohorts (Faroe Islands and Greenland). Levels of N3-PUFA in plasma phospholipids and Se in blood are relatively high. The moderate correlations observed between OC and MeHg concentrations in the Nunavik cohort may allow us to tease out the specific developmental deficits attributable to each toxin. Similarly, the weak correlations noted between environmental contaminants and nutrients will facilitate the documentation of possible protective effects afforded by either N3-PUFA or Se against neurotoxic contaminants.

Correlates of Infant Polychlorinated Biphenyls Body Burden at Birth and 6-Month Postpartum among the Northern Quebec Inuit

This paper was submitted to *Pediatric Research*.

Abstract

PCBs are food-chain contaminants that have been shown to induce adverse developmental effects in humans. In the course of an epidemiological study set up to investigate adverse neurodevelopmental effects induced by environmental PCB exposure in the Inuit population of Northern Quebec (Nunavik), we studied the intercorrelations among various measures of PCB body burden in Inuit infants at birth and at 6 months postpartum. Concentrations of 14 PCB congeners were measured by high-resolution gas chromatography with electron capture detection in lipids extracted from maternal plasma, cord plasma, breast milk (collected at approximately 1 month postpartum) and 6-month-old infant plasma samples. PCB congeners (PCB 99, 118, 138, 153, 180 and 187) were detected in more than 70% of biological samples. Similar congener profiles were observed in all biological samples and PCB 153, the most abundant and persistent PCB congener, was strongly correlated with the other frequently detected PCB congeners in all biological media. Maternal plasma, cord plasma and milk concentrations were strongly intercorrelated. PCB 153 plasma concentrations in 6-month-old infants were poorly predicted by maternal plasma concentrations alone. Multiple linear regression analysis revealed that a model that included maternal PCB 153 plasma concentration, the duration of breast feeding and an estimate of the infant body fat mass provided a good prediction of PCB 153 plasma concentration at 6 months postpartum ($r^2 = 0.71$; $p < 0.001$). Models developed in the present study may be used to reliably predict prenatal and postnatal exposure to PCBs in populations environmentally exposed to these compounds.

Determinants of Infant Polychlorinated Biphenyls Body Burden at 6-Month Postpartum among the Northern Quebec Inuit

This poster was presented at the PCB Workshop: Recent Advances in the Environmental Toxicology and Health Effects of PCBs, Lexington KY, 2000.

Levels and Determinants of Psychological Distress in Nunavik Mothers

This set of analyses was important to enhance our understanding of how socio-environmental factors may impact on the domains of infant development potentially affected by exposure to contaminants. The results of these analyses were presented to the Eleventh International Congress on Circumpolar Health, Harstad, Norway, 2000. These results were also published in Muckle et al. 2000.

Conclusions

The research activities planned for this year were performed. There are no results to present at this stage in relation to the study objectives, but extensive data on prenatal exposure as well as on determinants of PCB exposure have been submitted for publications during year 2000-2001. At the end of the year 2001-2002, data collection will terminate and statistical analyses designed to look at neurobehavioural effects of prenatal PCB exposure during the first year of life will be performed. Manuscripts focussing on effects analyses should be submitted to international journals for publications in 2002.

Expected Project Completion Date

March 2002

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Contaminants and Human Health in the Canadian Arctic: an Update

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Abstract

The Northern Contaminants Program (NCP) is midway through its second phase, and is at a stage in which several multi-year human health-related studies have been recently completed or are nearing completion. Meanwhile, the NCP and the Arctic Monitoring and Assessment Programme are gearing up for their next major assessment reports. Consequently, a need was identified to take stock of the new state of knowledge with respect to contaminant exposure, effects, toxicology, and benefits and risks of traditional/country food consumption, and to synthesize results in a broader context. A workshop, Contaminants and Human Health in the Canadian Arctic: an Update, organized by the NCP Human Health Review Team, was held in Ottawa, Ontario on February 7 and 8, 2001. It brought together approximately 60 key researchers and others with an interest in contaminants and health in the North to focus on contaminants-related research and results since the 1997 *Canadian Arctic Contaminants Assessment Report*. These recent findings will be used to revise the NCP Blueprints, as appropriate, and plan for Phase III. This report summarizes presentations given at the workshop; full proceedings of the workshop will be available by the fall of 2001.

Key Project Messages

1. There is a need to take stock of new information on contaminant exposure, effects, toxicology, and benefits and risks of traditional/country food consumption, and to synthesize these results in a broader context of overall health in the North.
2. A workshop was held in February 2001 so that scientists and others identified as having an interest in contaminants and health in the North could

discuss recent study results, identify knowledge gaps and draw conclusions.

3. The information presented and discussed at this workshop will be incorporated in the upcoming major assessments by the Northern Contaminants Program (NCP) – the *Canadian Arctic Contaminants Assessment Report* II – and by the Arctic Monitoring and Assessment Programme (AMAP), and will be used when revising NCP blueprints and setting priorities for NCP Phase III.

Objectives

1. To examine the new state of knowledge with respect to contaminant exposure in the North, effects and toxicology, as well as benefits and risks of traditional/ country food consumption, and to synthesize results in a broader context.
2. To hold a workshop on human health and contaminants in the North, which focuses on contaminants-related research and results since the 1997 *Canadian Arctic Contaminants Assessment Report* (CACAR).
3. To facilitate the incorporation of new findings on human health and contaminants in the upcoming major assessments by the NCP and AMAP, in revisions to the NCP blueprints and in priorities for NCP Phase III.

Introduction

In 2000-2001, the NCP was midway through its second phase, and was at a stage in which several multi-year human health-related studies had been recently completed or were nearing completion. At the same time, the NCP and AMAP were gearing up for their next major assessment reports. Consequently, a need arose to take stock of the new state of knowledge with respect to contaminant exposure, effects, toxicology, and benefits and risks of traditional/country food consumption, and to synthesize results in a broader context.

To address this need, members of the NCP Human Health Review Team undertook the planning of a workshop on human health in the North, which would focus on contaminants-related research and results since the 1997 publication of CACAR (Jensen et al. 1997). This workshop was organized so that it would serve as an opportunity for researchers to present and discuss recent data and come to scientific consensus on the current state of knowledge, and, together with representatives of health boards, contaminants committees and Aboriginal organizations, to address any implications of these findings for a benefit/risk communication strategy. It would also provide an opportunity to identify gaps in scientific knowledge, which will be useful in making revisions to NCP blueprints and setting priorities for NCP Phase III.

An NCP workshop with similar objectives held in June 1997, The Northern Health Initiative Workshop, served "to gather information on all health related activities underway or required in the Arctic regions," with a focus on exposure to contaminants through traditional foods, water and air (Van Oostdam 1997). The objectives for a workshop in 2000 built upon recommendations that emerged from the 1997 workshop.

Activities in 2000-2001

A 2-day workshop, Contaminants and Human Health in the Canadian Arctic: an Update, was held in Ottawa on February 7 and 8, 2001. An abridged agenda is in Table 1.

Leaders of research in several contaminants and health-related fields who had conducted research under the NCP during NCP Phase II (since 1997), were invited to present an overview and synthesis of the state of knowledge in their particular field of expertise. Presenters were requested to draw upon research done within and outside of the NCP, and to provide a summation of current work being conducted by their research group, as well as by others. Presenters were also asked to provide a five- to six-page paper, including an executive summary, addressing the following: the current understanding about their topic; the potential implications of new information in terms of benefit/risk communication messages and recommendations in the North; whether or not the recommendations from CACAR still hold in light of new information in the 5 years since its publication; and an indication of knowledge gaps and priorities.

Attendance at the workshop was by invitation only. Invitations were extended to: researchers in fields related to contaminants and benefit/risk assessment of traditional/ country foods from research institutes, universities and federal departments; territorial health and social services departments and regional health committees; territorial contaminants committees; Aboriginal partners organizations; and regional contaminants coordinators. All workshop attendees participated in break-out sessions discussing either: research gaps and modification of the NCP blueprints; or conclusions and development of key messages.

Results and Discussion

Approximately 60 people participated in the 2-day workshop, Contaminants and Human Health in the

Table 1. Abridged agenda of the Northern Contaminants Program workshop – Contaminants and Human Health in the Canadian Arctic: an Update – held February 7-8, 2001

TOPIC	SPEAKER
Opening Remarks	Russel Shearer, DIAND Jose Kusugak, Inuit Tapirisat of Canada
Session A: Exposure to Contaminants	**Chair: Mark Feeley, Health Canada**
Dietary Surveys: What Have We Learned?	Olivier Receveur, University of Montreal
Maternal and Cord Blood Contaminants in Arctic Canada	Jay Van Oostdam, Health Canada
New, Unique Compounds	Derek Muir, Environment Canada
Session B: Experimental Toxicology	**Chair: Mark Feeley, Health Canada**
Toxicological Consequences of Toxaphene Ingestion by Cynomolgus (*Macaca fascicularis*) Monkeys	Douglas Arnold, Health Canada
Toxicity of Chlordane-Related Food Contaminants	Genevieve Bondy, Health Canada
Toxicological Effects Induced by Exposure to Complex Food-Chain Contaminant Mixtures	Pierre Ayotte, Laval University Hospital Centre, CHUQ
Radioactive Contaminants in the Canadian Arctic: Health Implications	Bliss Tracy, Health Canada
Effects of Nutrient Interactions on Methylmercury Toxicity: Current Understanding and Research Initiatives	Laurie Chan, Centre for Indigenous Peoples' Nutrition and Environment
Session C: Epidemiological Studies	**Chair: Sarah Kalhok, DIAND**
Neurodevelopmental Studies of Prenatal Mercury Exposure	Gina Muckle, Laval University Hospital Centre, CHUQ
Neurodevelopmental Studies of Prenatal Polychlorinated Biphenyl Exposure	Gina Muckle, Laval University Hospital Centre, CHUQ
Other Biomarkers	Éric Dewailly, Laval University Hospital Centre, CHUQ
Adverse Effects on the Immune System Induced by Exposure to Food-Chain Contaminants in the Arctic	Pierre Ayotte, Laval University Hospital Centre, CHUQ
Session D: Northern Health Perspectives	**Chair: Allison Armstrong, Dene Nation**
Territorial and Nunavik Health Perspectives on Benefit-Risk Communication	Erica Myles, GNWT Health Chris Furgal, Nunavik Nutrition and Health Committee
Aboriginal Perspectives on Contaminants and Health	Eric Loring, Inuit Tapirisat of Canada
Summary of Presentations	Andrew Gilman, Health Canada
Break-Out Groups: • Research Gaps and Northern Contaminants Program Human Health Blueprints • Conclusions and Development of Key Messages	
Reports from Break-Out Group Chairs in Plenary	
Closing Remarks	Russel Shearer, DIAND

Canadian Arctic: an Update. The following are summaries of presentations that were provided in advance of the meeting. Proceedings of the workshop, including full papers/presentations and summaries from the break-out groups, will be available from the NCP Secretariat by the fall of 2001.

Session A: Exposure to Contaminants

A1. Dietary surveys: what have we learned?

Harriet Kuhnlein, Centre for Indigenous Peoples' Nutrition and Environment (CINE), Olivier Receveur, University of Montreal, and Laurie Chan, CINE

In 1997, data from harvest studies, and from dietary surveys conducted in Sanikiluaq, Broughton Island, Wood Buffalo Park area, Fort Good Hope and Colville Lake, and four Yukon communities, together with preliminary results from the CINE study in 16 Dene/Metis communities were used to contribute to the main objectives of CACAR, (i.e. to assess the impact on human health of exposure to current levels of environmental contaminants; and to identify the data gaps for future human health research and monitoring). Conclusions reached at that time included:

1. Traditional food is central to the culture of Arctic Indigenous peoples.
2. Traditional food is an economic necessity.
3. Traditional food is an important source of nutrition.
4. Traditional food consumption varies widely both in type and quantity across communities;
5. The trend toward increased market food consumption, most noticeable among the youth, is likely to have adverse health effects in terms of nutritional status as well as risk of chronic disease.
6. Traditional food can also be a significant source of contaminants and the potential risks associated with exposure to multiple contaminants must be assessed and balanced against the better known benefits this food provides.

Since then, data collection was completed in 10 Yukon and 18 Inuit communities, following very closely the methods previously used in 16 Dene/Métis communities. The conclusions reached in 1997 based on limited data can now be generalized with confidence to the Canadian Arctic and much of the data needed for evaluating dietary benefits and risks are now available[1]. For example, diets are described in terms of diversity of traditional and market food use, relative nutritional contributions of traditional and market food, and socio-economic and cultural attributes. Contaminants exposure levels are presented across regions, across age-groups, by food sources, and the distribution of these exposure levels are being compared to guidelines. Estimates of contaminant exposure were shown to be similar or lower than estimates available in 1997. At present, available estimates of dietary intakes and contaminants exposure can be used in benefit/risk analyses. These estimates, which could be improved with a limited number of additional food composition data and probabilistic description of exposure levels, need to be linked with estimates of health risks and benefits. To obtain estimate of health risks and benefits will require a critical review of the extensive literature available in nutritional sciences, as well as the more limited but growing understanding of the health risks associated with the levels of contaminants of concern. While a great deal of research interest centres on the development of benefit/risk analyses[2], data already at hand can be used to provide useable information for personal decision making to maximize diet quality and minimize contaminant exposure. The need to improve the quality of market food is obvious in most communities as is the need to address the constraints to food choices, particularly among the youth in order to prevent the dramatic rise in chronic diseases that can be expected based on completed dietary assessments.

A2. Maternal and cord blood contaminants in Arctic Canada

Jay Van Oostdam, Arctic Section, Bioregional Programs, Health Canada Health Canada

The 1994-2000 sampling of maternal tissues in Arctic Canada has allowed a baseline assessment of environmental contaminants in most regions of the North. Polychlorinated biphenyls (PCBs) are found at significantly higher levels in Inuit mothers and their infants, and Baffin Inuit have the highest levels in the regional studies conducted to date. A similar pattern has emerged for contaminants such as oxychlordane and *trans*-nonachlor, two derivatives of chlordane. Mercury (Hg) is also found at the highest concentrations in Inuit, and mothers from Nunavik have the highest maternal levels in the Canadian Arctic. Inuit mothers from Greenland have higher levels of many of these contaminants. For β-HCH (beta hexachlorocyclohexane) and DDE, the highest levels were seen in the 'other' mothers who had recently come from southeast Asia or Africa. β-HCH and DDE are still widely used in these regions. In comparing maternal and cord blood levels it was noted that Hg levels were 1.5 to

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[1] For final reports from each of these three large dietary surveys, check www.cine.mcgill.ca for a complete list of references.

[2] See for example: Ponce et al. 2000. Use of quality-adjusted life year weights with dose-response models for public health decisions: a case study of the risks and benefits of fish consumption. *Risk Analysis* 20(4).

1.8 times higher in cord blood as has been found in other studies. Organochlorines such as PCBs were generally found at 0.7 to 0.9 times the maternal concentrations. A few organochlorines were noted to be 1.4 to 3.2 times the concentrations found in maternal blood. Some data is emerging for contaminant such as PCBs and Hg which indicate that more recent levels may be lower than those levels seen in the 1980s but any conclusions based on only two data points need to be extremely cautious.

A3. New and emerging persistent organic pollutants

Derek Muir, National Water Research Institute, Environment Canada

This presentation summarizes the current information on new chemical contaminant issues that are emerging in the Arctic. Unique characteristics of the Arctic – such as proximity to industrial areas of Europe and North America, long food chains with top predators that are also traditionally consumed by humans, and cold, ice covered seas – make the region vulnerable to persistent organic pollutants (POPs) like PCBs, chlorinated dioxins, and chlorinated pesticides, as well as Hg. Until recently, the focus of NCP as well as similar AMAP-related programs in other circumpolar countries was on the PCBs and chlorinated pesticides, and to a lesser extent, chlorinated dioxins/furans – because of the widespread capacity to make accurate measurements of these chemicals, as well as their known toxicity and biomagnification potential. International agreements are in place (although not ratified completely) that will ban or limit the emissions of "old" POPs and toxic metals like Hg. Temporal trend studies show that there are declines of PCBs and DDT in some species (e.g. seabirds) but not in others (e.g. seals, beluga). Mercury levels, on the other hand, appear to be increasing in Arctic marine animals. However, there are many other chemicals in current use that are also potentially persistent, bioaccumulative and toxic (PB&T) based on similar physical properties, structural similarity to the "old POPs" and, in some cases, known toxicology. Environment Canada's Commercial Chemicals Evaluation Branch (CCEB) has recently identified 100 chemicals with possible PB&T properties as part of its evaluation of chemicals in commerce in Canada. However, < 10% of the chemicals on the CCEB list have been determined in the Arctic or anywhere else in North America. Progress has been made on measurement of a few chemicals that resemble the "old POPs." These chemical groups are chlorinated paraffins, chlorinated naphthalenes and brominated diphenyl ethers. Recent results on measurement of these "new" POPs in Arctic biota and air will be reviewed. Another group, the perfluoroalkane-sulfonates (part of the product "ScotchGard"), have also unexpectedly been detected in Arctic biota. The presence of these fluorinated chemicals, which have quite different physical properties and mode of toxicity compared to the traditional POPs, but appear to be equally persistent, illustrates the need to be continually vigilant about the global movement and bioaccumulation of organic chemicals.

Session B: Experimental Toxicology

B1. Toxicological consequences of toxaphene ingestion by cynomolgus (Macaca fascicularis) monkeys

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Toxaphene, a mixture of polychlorinated monoterpenes, was initially sold in 1945 by Hercules Co. as Hercules 3956. It was the most heavily-used pesticide in the U.S. and in many parts of the world prior to its being banned in the U.S. Most registered usages of toxaphene in Canada were cancelled in 1980 and similar actions were undertaken in other countries prior to the U.S. Environmental Protection Agency (EPA) cancelling most toxaphene registrations in 1982. The EPA had concluded that the use of toxaphene posed risks of : 1) chronic effects to wildlife; 2) acute toxicity to aquatic organisms; 3) population reduction in non-target organisms; and 4) increased potential for oncogenicity in humans. At the time, it was well known that the prevailing winds had transported toxaphene over long distances. Subsequently, toxaphene residues were found consistently where toxaphene was either never used or not used to any significant extent. The implications of these observations were evident when reports started to appear that the mean concentration of organochlorines in the milk fat samples obtained from Inuits were two to 10 times greater than in similar samples collected in southern Quebec, and that traditional diets exceeded the "tolerable daily intake levels" for toxaphene.

Because of these findings, and the general lack of toxicological data regarding toxaphene that conforms to the present standards, the following study was undertaken. Forty female and two groups of five male cynomolgus monkeys were used in this study. The females self-ingested capsules containing dosages of 0, 0.1, 0.4 or 0.8 mg of technical grade grade toxaphene·kg bw^{-1}·d^{-1}. The older males were proven breeders and were used exclusively for mating. Their capsules contained no toxaphene. The younger males' capsules contained 0.8 mg of toxaphene·kg bw^{-1}·d^{-1}. Statistical analysis did not reveal any effect of treatment upon body weight gain, feed consumption, water consumption or hematological parameters during the 75 weeks pre-mating phase. The only serum biochemistry parameter which was consistently affected by treatment was cholesterol which decreased in a linear fashion as a consequence of dose; this difference increased with time on test ($p = 0.037$). The no observed effect level regarding immunological effects in the females was 0.1 mg·kg^{-1}. During mating, toxaphene did not affect: the number of matings needed to achieve impregnation ($p > 0.05$); the ability to maintain pregnancy ($p = 0.41$); gestation length ($p = 0.010$); sex ratios ($p = 0.85$); or birth weights ($p > 0.25$). However, toxaphene did: increase femur length at gestation day 150 ($p = 0.037$); increase the dam's % reticulocytes ($p = 0.0016$) while decreasing cholesterol levels ($p \leq 0.0024$) and thyroxine uptake ($p = 0.003$). Toxaphene also increased neonatal female growth rate ($p = 0.0047$) and decreased the male's birth weight ($p = 0.047$) and growth rate ($p = 0.040$).

B2. Toxicity of chlordane-related food contaminants

Genevieve S. Bondy, Michael Barker, Gerard Cooke, Ivan Curran, Mark Feeley, Santokh Gill, Eric Lok, Rekha Mehta, Harvey Newsome, Olga Pulido, Paul Rowsell, Helen Tryphonas, Bureau of Chemical Safety, Food Directorate, Health Canada, Ottawa

The pesticide chlordane, which is a mixture of structurally related organochlorine compounds, was widely used in North America until the 1980s. As a result of its stability and persistence it has accumulated in the environment and can be detected in foods and in human tissues and breast milk. Some Canadians are exposed to chlordane at levels higher than the Health Canada provisional TDI of 0.05 μg·kg bw^{-1}·d^{-1}, particularly those consuming traditional diets high in marine mammal fats. In rodents, chlordane causes changes in the liver by inducing microsomal enzymes. In long term rodent studies, chlordane causes benign and malignant liver tumours. Other effects of chlordane on rodents include altered immune function and thyroid changes. In humans the acute effects of chlordane exposure include gastrointestinal upset, tremors and convulsions. The data for chlordane carcinogenicity in humans is weak, but the blood cell system and not the liver may be the target for potential chlordane-related carcinogenicity in humans. Most of the toxicological data for chlordane focus on the chlordane mixture, although *trans*-nonachlor and its metabolite oxychlordane are the most plentiful chlordane contaminants in traditional/country foods and human tissues. Health Canada/NCP studies indicate that these major constituents may also be among the most toxic of the chlordane contaminants. Suggested future studies should include: long-term oxychlordane and *trans*-nonachlor exposure studies in rodents; multi-generational rodent reproductive studies focussing on oxychlordane/*trans*-nonachlor; investigations of the potential link between chlordane exposure and hematopoietic effects in humans.

B3. Toxicological effects induced by exposure to complex food-chain contaminant mixtures

Pierre Ayotte, Public Health Research Centre-CHUQ (CHUL)

Most toxicological studies performed on POPs have focussed on individual compounds or technical mixtures, rather than on complex mixtures as they are found in the environment. Interactions between substances in a complex mixture may result in antagonism, additivity or synergism. In the few studies that were conducted on mixtures relevant to the Arctic environment, animals received either a reconstituted mixture or lipids extracted from wildlife species that contain relatively high concentrations of organochlorines. We conducted a developmental study using the pig as the animal model to investigate the effects on reproductive and immunological endpoints of in utero and lactational exposure to a reconstituted mixture similar to that found in blubber samples from northern Quebec seals. Administration of the mixture caused a reduction of body length at birth, and of testis weight and sperm motility in sexually mature boar. With regard to immunological effects, administration of the mixture (high dose) caused a decrease in the proportion of animals showing sustained antibody titres following vaccination against *Mycoplasma hyopneumoniae*. No effects attributable to contaminants were noted in other studies that investigated the toxicity of mixtures relevant to the Arctic environment.

B4. Radioactive contaminants in the Canadian Arctic: health implications

Bliss Tracy, Radiation Protection Bureau, Health Canada

Since the publication of the first CACAR report, research at Health Canada on radionuclides has focussed on the uptake of radioactive ^{210}Po through the lichen → caribou → human food chain. A two-year study, funded by the NCP, has just been completed with the University of Saskatchewan. Measurements of ^{210}Po in excreta from 14 volunteers from Saskatoon who consumed known amounts of caribou meat confirmed that more than 50% of ingested polonium was absorbed by the human gastrointestinal tract. The retention time was found to be more than twice as long as the expected 50 days. Both of these factors mean that radiation doses to northern populations consuming caribou meat is significantly higher than expected. A further study has been undertaken, funded by the Toxic Substances Research Initiative, to measure the effects of ^{210}Po alpha radiation at the cellular and subcellular level. The first phase involved the irradiation of cultured bovine endothelial cells at the University of Saskatchewan. Results from this phase have allowed an estimation of the relative biological effectiveness of alpha radiation compared to 250 kvp x-rays for cell lethality and reproductive capability in this animal system. Work is proceeding on the scoring of chromosome aberrations in the bovine cells. Human blood lymphocytes are also being cultured and subjected to the same treatment. This technique will be applied to northern populations consuming large amounts of caribou meat. It will be possible to detect subtle changes at the chromosome level long before clinical health effects become visible.

Emerging radiological health issues at the local level include the past exposures of uranium ore carriers from the community of Deline, NWT, and also the current impact of the Port Radium mine site on members of the community. Concerns have also been raised about diamond mines and a proposed beryllium mine in the NWT which can bring radioactive materials to the surface in the form of waste rock. Contaminants from nuclear facilities and other industrial operations in the temperate zone can be transported to northern regions by global atmospheric circulation patterns. Radionuclide measurements, aided by sophisticated computer models, are being used to unravel these circulation patterns.

B5. *Effects of nutrient interactions on methylmercury toxicity: current understanding and research initiatives*

Laurie Chan, Centre for Indigenous Peoples' Nutrition and Environment

Several epidemiological studies have been conducted to study the health effects of exposure to methylmercury (MeHg) through fish and marine mammal consumption in different geographical areas: the Seychelles, the Canadian North, the Amazon, the Faroe Islands, Papa New Guinea and Sweden. There are inconsistencies in the lowest observable effect dose; for example the populations in the Amazon appear to be more sensitive. It has been suggested that dietary practice may be a significant factor affecting the susceptibility to MeHg. Of all nutrients, selenium (Se) has received the most attention as a potential protector against MeHg toxicity, particularly among seafood consuming populations, because the main sources of Hg in their diet are also rich sources of Se. Some studies have reported a correlation between Se and Hg in the serum or plasma, while others did not observe such a correlation. No epidemiological studies however, have ever shown a correlation between Se intake and the occurrence or absence of symptoms for MeHg intoxication. There are also inconsistencies in the protective effects seen in animal studies. The role of selenium remains to be confirmed. Macronutrients such as fat intake have also been correlated with MeHg toxicity. A positive correlation between dietary Hg and low density lipoprotein-cholesterol has been observed. Unsaturated fatty acids were also correlated with Hg exposure in populations frequently consuming seafood and fish, and there are suggestions that omega-3 fatty acids, particularly docosahexaenoic acid, may have beneficial effects. Since most studies did not collect sufficient detailed dietary information, exactly how dietary modifications, besides decreased consumption of Hg containing foods, can affect the risk of MeHg toxicity is still unclear. Even though there is little evidence of nutrient effects at the population level, there is plenty of evidence that nutrients interact with the metabolism of Hg at the physiological level. Nutrients can affect the bioavailability, the toxico-dynamics, the transport to target organs, and influence the immunological, biochemical or cytological functional responses to Hg. However, similar to the limited understanding of the mechanisms of MeHg toxicity, the overall mechanisms of modification of MeHg toxicity by nutrients are not well understood. This review paper provides an overview of our current understanding of how dietary factors affect MeHg toxicity and discuss some of the current research projects.

Session C: Epidemiological Studies

C1. *Neurodevelopmental studies of prenatal mercury exposure*

Gina Muckle, Public Health Research Centre-CHUQ (CHUL)

Since the publication of CACAR, there are new data indicating that prenatal exposure to MeHg resulting from fish and marine mammal consumption may be associated with negative neurodevelopmental effects, particularly in the domains of fine motor function, attention, language, visual-spatial abilities and verbal memory. However, there are dietary, economic, and cultural particularities of the Inuit lifestyle that required to be considered in the risk-management process. The ongoing prospective cohort study on the neurobehavioural effect of perinatal exposure to environmental contaminants have progressed well in Nunavik and this study will test the important hypotheses for Aboriginal Northerners that PCBs may modify the effects of MeHg, and that adverse neuro-behavioural effects from exposure to environmental contaminants may be attenuated by high intake of Se and N3-polyunsaturated fatty acids. These nutrients are found in diets rich on fish and marine mammals. Community actions should be postponed until the results of this study go through the peer review process.

C2. *Neurodevelopmental studies of prenatal polychlorinated biphenyl exposure*

Gina Muckle, Public Health Research Centre-CHUQ (CHUL)

Since the publication of CACAR, there is no new data indicating that postnatal exposure to PCBs or other OCs via breast-feeding might be associated with negative neurodevelopmental effects at birth, and during infancy and childhood. Consequently, the recommendations formulated in CACAR regarding the encouragement of breast feeding due to its well-known benefits for the infants health and mother-child attachment should be maintained. Even if there is a growing body of evidence linking prenatal PCB exposure to neurobehavioural subtle deficits during infancy and childhood, there are dietary, economic, and cultural particularities of the Inuit lifestyle that required to be considered in the risk-management process. The ongoing prospective cohort study on the neurobehavioural effect of perinatal exposure to environmental contaminants have progressed well in Nunavik and this study will test the important hypothesis for Aboriginal Northerners that adverse neurobehavioural effects from exposure to environmental contaminants may be attenuated by high intake of selenium and N3-polyunsatirated fatty acids resulting from a diet rich on fish and marine mammals. This information is needed to the benefit/risk characterization process and community actions should be postponed until the results of this study go through the peer review process. However, this should not delay the implementation of international actions aimed at reducing the increase of PCBs and other OCs in the environment.

C3. Effect biomarkers for people exposed to metals and POPs in Canada's Arctic region

Éric Dewailly, Frederic Dallaire and Daria Pereg, Public Health Research Unit-CHUQ (CHUL) and Laval University

The inclusion of validated biomarkers in epidemiological studies may help in identifying relevant associations between exposure to contaminants and detrimental health effects in the Inuit population. Over the past decade most of our efforts were focused on the characterization of exposure of Northerners. Epidemiological studies are now in place or in preparation. For most of these studies, health outcomes of interest are clinical: psychometric, neuro-physiologic, infection incidence, bone density and sexual maturation among others. However, knowing the mechanism of action of most toxicants and attempting to detect early biological changes preceding overt diseases, effect biological markers need to be validated and used. Effect biomarkers are early biological responses of the organism to an external toxic stress. The inclusion of validated biomarkers in epidemiological studies may help in identifying relevant associations between exposure to contaminants and detrimental health effects in Northerners.

C4. Adverse effects on the immune system induced by exposure to food-chain contaminants in the Arctic

Pierre Ayotte, Public Health Research Centre-CHUQ (CHUL)

Studies in laboratory animals and wildlife species have shown that exposure to organochlorine compounds can compromise immune system function and increase susceptibility to infectious diseases. In view of the relatively high exposure to OCs in the Inuit population and the very high incidence of certain infectious diseases in the Arctic, in particular respiratory tract infections and otitis media, we conducted a cohort study in the early 1990s to test the hypothesis that prenatal organochlorine exposure is associated with the incidence of infectious diseases in Inuit infants from Nunavik (Arctic Quebec). Prenatal exposure to organochlorine was assessed by measuring the concentration of organochlorines in breast milk fat. We found an increased risk of otitis media during the first year of life with increasing prenatal exposure to some organochlorines compounds such as *p,p'*-DDE and hexachlorobenzene. The only comparable study involved a cohort of infants from Rotterdam (the Netherlands) and no association was reported between PCB or dioxin exposure and the incidence of infectious diseases. We are presently trying to replicate our initial findings in the course of the infant development study, which is approaching completion in Nunavik. The study design will allow a better characterization of exposure to OCs and to fully control for possible confounding factors.

Session D: Northern Health Perspectives

D1. Territorial health perspectives on benefit/risk communication

Erica Myles, GNWT Health and Social Services

The health status of northern Canadians depends on many factors outside of the traditional health care system. Social, economic, environmental and personal factors all play important roles in determining health. Under this broad population health approach, health cannot be achieved in isolation. Progress in other areas including environmental protection and social well-being are needed to make improvements in the health of a population. It is under this broad approach to health, that the issue of human health and environmental contaminants is addressed. It is also under this broad approach that health risks associated with environmental contaminants are communicated. Over the past decade the GNWT Department of Health and Social Services has worked actively to communicate information on contaminants and human health to NWT residents. The collaborative approach of Cooperative Risk Management has been used to develop balanced messages when communicating results of health hazard assessments, and to communicate general information on contaminants and human health. Essential to this process is the involvement of local communities, to ensure a two way exchange of information and to increase community participation in decision making. The renewal of people's confidence in the consumption of traditional foods, is the key objective of many communication materials produced. The consumption of traditional food is vital to the health, nutrition and culture of northern Canadians. The health risks associated with not consuming these foods are significant, as nutritious and economic alternatives to country/traditional food are very often not available. Subsequently, benefit/risk communication has focussed on promoting the nutritional, social and cultural benefits of traditional food consumption. Continued international action to reduce the levels of contaminants in the northern food chain remains important. As new information becomes available on the risks and benefits associated with the consumption of northern traditional foods, communication materials and key messages need to reviewed and updated. Now may be a key time to review past messages and communication materials, to ensure that residents are still receiving the necessary information to make informed decisions that will effect their health. Whether key messages change or remain the same, the importance of communicating balanced messages under a broad population health approach will remain constant.

D2. Communicating on health and contaminants in Nunavik

Chris Furgal, Nunavik Nutrition and Health Committee, Nunavik, and Public Health Research Unit-CHUQ; Minnie Grey, Nunavik Nutrition and Health Committee, Nunavik, and Nunavik Regional Board of Health and Social Services; Suzanne Bruneau, Nunavik Nutrition and Health Committee, Nunavik, and Public Health Research Unit-CHUQ

Traditional/country food is central to the cultural and personal well-being of Northerners. It is essential to the nutritional and social health of indigenous individuals. For some, few nutritious and affordable alternatives are accessible. Despite their vital importance, significant changes in the collection, use, consumption and attitudes towards these food sources have occurred over the past two decades, in part, due to the realization of and reported presence of industrial pollutants in the Arctic ecosystem. In Nunavik, a group of concerned individuals representing different organizations concerned with health, the environment, and nutritional issues has formed to address these issues, and communicate to and educate the public so that they may make more informed decisions on these issues. The Nunavik Nutrition and Health Committee, evolved from the PCB Resource Committee that originated in 1988. Between 1988 and 1994, this committee prepared and distributed written documents, participated in radio interviews, prepared videos, and discussed in various forums the issues related to food chain contamination associated with country food consumption and breast feeding. As it appeared unrealistic to consider environmental risks without integrating them into a wider health framework, the PCB Resource Committee was renamed the Food, Contaminants and Health Committee in 1994 to formally recognize this shift in perspectives and simultaneously consider both benefits and risks. In 1996 this committee was merged with the Avativut/Ilusivut (Eco-Research) Steering Committee to form the Nunavik Nutrition and Health Committee to consider not only research and communication on risks, but also different levels of benefits and health issues associated with the various foodstuffs or food preparation and transformation practices in Nunavik. The scope of the committee has broadened through time to contextualize and communicate scientific information on contaminants, health and nutrition within a framework that is more responsive to the population's needs and the multiple factors influencing health. This evolution is reflected in the approaches to communication, health promotion and education taken by the Nunavik Regional Board of Health and Social Services. Valuable lessons have been learned through practice and research in this region regarding the delivery of balanced messages on these issues based on the best known science to date, all the while promoting healthy diet and lifestyle behaviours.

D3. Aboriginal Perspectives on Contaminants and Health

Eric Loring, Inuit Tapirisat of Canada

Northern Aboriginal people rely on traditional/country food, which they hunt and harvest from the land, for much of their nutritional intake, their cultural identity and for economic reasons. A traditional diet is healthy and well balanced; however, reports of heavy metals, radionuclides and persistent organic pollutants in traditional/country food sources have compromised the confidence northern Aboriginal peoples have in their food. Community members are confused and scared when they hear that their traditional/country food is contaminated – they need an answer to their question, "Is my food safe to eat?" Southern food is available in the North but the choices are limited, costs are high and the nutritional value is questionable. Further, there is more to traditional/country foods than nutrition. With it comes socio-cultural, economic and environmental benefits, as well as a knowledge of the land and the animals; it is often said, "When I eat traditional food I know who I am." Communicating knowledge on contaminants to Aboriginal people without creating fear and confusion is not an easy task. Levels of contaminants in ppm and substances with technical names mean very little to community members. Aboriginal people need to know in plain language what chemicals and how much is in the water, soil, sediment, air, wildlife and people, how much is getting into "me" and from where, and – perhaps the most important piece of information, and the hardest to obtain and communicate – what are the benefits versus the risks of continuing to consume traditional/country food.

Work has, and is, being undertaken to determine the relative risks of exposure to contaminants through consuming a traditional diet versus the nutritional, cultural, spiritual and economic implications of changing to a western diet, but more research on the effects of the levels of contaminants found in the Arctic and in traditional/country foods is needed. We can provide information on where and how the contaminants are coming from but we cannot tell the community members what it means to them. Since 1991, the Aboriginal partners and community members have become far more knowledgeable about the issues related to contaminants in the Arctic and have engaged community members in many studies, allowing traditional knowledge to become incorporated. Each year, more community-driven projects are being proposed. They have influenced Canadian domestic and international positions and gone to the United Nations where they enlightened the world to the unique environment of the Arctic and the value of the culture of Arctic indigenous peoples. Yet, we must still work harder to improve our ability to answer the question "What does this all mean to me?".

Conclusions

The workshop, Contaminants and Human Health in the Canadian Arctic: an Update, brought together approximately 60 key researchers and others with interests in contaminants and health in the North to focus on contaminants-related research and results since the 1997 CACAR. Through a series of presentations and question-and-answer periods, workshop participants examined the new state of knowledge with respect to contaminant exposure in the North, effects and toxicology, as well as benefits and risks of traditional/country food consumption. In smaller working groups, participants also discussed research gaps and modifications to the NCP blueprints and, as an initiative to synthesize results in a broader context, looked at the conclusions that could be drawn and how these could be developed into key messages for delivery in the North.

Information presented and discussed at this workshop is being incorporated in the major assessments by the NCP – the *Canadian Arctic Contaminants Assessment Report* II – and by AMAP, both of which are scheduled for release in Fall 2002. This information will also be used in revising NCP blueprints and setting priorities for NCP Phase III.

Expected Project Completion Date

The workshop was held in February 2001; full proceedings of the workshop will be available by the fall of 2001.

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Inuvik Regional Human Contaminants Monitoring Program: Communication Activities

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Abstract

The Inuvik Regional Health and Social Services Board initiated the Inuvik Regional Human Contaminants Monitoring Program in 1997. The overall objective of this study was to establish baseline levels of specific heavy metal and organochlorine contaminants in the blood of women and their newborns from communities in the Inuvik Region, Northwest Territories. Collection of data from this region completed the Northwest Territories database, since this type of data has already been gathered from all other Health Board regions of the Northwest Territories and Nunavut. Results of this program can be found in the *Synopsis of Research Conducted Under the Northern Contaminants Program* 1999-2000 (Walker et al. 2000), as well as in the regional report (Tofflemire 2000). Relationships were explored between contaminant levels in maternal blood and contaminant levels in neonatal blood. The program also described the relationships of contaminant exposure through the consumption of traditional food, and through certain other lifestyle factors. The focus of the 2000-2001 fiscal year was to distribute individual results, communicate regional results to communities, produce and disseminate a regional report and continue with educating professionals and the general public regarding contaminants in the North. The project came to a close in July 2000.

Key Project Messages

1. Most contaminants measured were found in low levels in the Inuvik region. The results tended to be lower than in the Eastern Arctic and other regions, such as Greenland.
2. Traditional food consumption is important for women of reproductive age.

3. Education and communication of results are essential to the success of a research initiative. Communications should take place throughout all aspects of the program, starting at its creation, and continue following the production of reports.

Objectives

1. To communicate the results of the Inuvik Regional Human Contaminants Monitoring Program to participants, communities and all interested parties, and to contribute to the territorial database on levels of environmental contaminants in Northerners.
2. To inform and educate professionals in the environmental and public health field.
3. To serve as a resource and disseminate timely information, to allow for Inuvik region residents to make informed decisions regarding their health, lifestyle and environmental contaminants.

Introduction

Increasing concern surrounding long-range transport of contaminants prompted studies to establish a baseline of contaminant levels existing in Northerners, particularly among vulnerable populations, such as mothers and newborns.

Contaminants of concern are released into the environment from around the world, and carried northward by atmospheric and marine pathways. This study explores contaminant exposure from both traditional food consumption and lifestyle factors, while examining organochlorines and metals in maternal and umbilical cord blood, as well as mercury levels in maternal hair.

The program had a total of 104 participants from the Inuvik region. During the sample collection period of June 1998 to June 1999, a total of 185 blood samples were taken (95 maternal and 90 cord), 73 hair samples were given and 102 questionnaires were completed. Low levels of contaminants were found in the samples. The results of this program (Walker et al. 2000, Tofflemire 2000) were similar to existing data from other regions in the Canadian North, in particular, the western Arctic, Mackenzie region (Walker and Corriveau 1998). Levels of exposure to contaminants were generally within guideline levels, with only a few exceptions. This study also confirms the importance of traditional food among women of reproductive age.

The importance of timely communication of results cannot be underestimated. It has been shown that a need exits for development of communications in the local communities. This includes use of multiple media and pathways to deliver messages to a wider audience, and the need to deliver both risk and benefit information on these topics (Lampe et al. 2000). Similar discussion groups have also visited this conclusion, stating, "it is the utmost importance (and respect) to report findings back to the community – in plain language." (Dene Nation 2000). The Inuvik Regional Human Contaminants Monitoring Program aimed to meet the needs of the region with respect to communications and made communication the focus of the conclusion of the project.

Activities in 2000-2001

The communications and report generation phase of the project was completed between April and July 2000.

Reports and articles

- Arctic Monitoring and Assessment Programme Project Directory registration.
- Summary for Aurora Research Institute, Inuvik, NT.
- A summary of the project was prepared for the State of Alaska, Governors Office, upon request for current studies on northern contaminants.
- A regional report (Tofflemire 2000) was compiled to summarize the findings of the program. The report covered a background concerning contaminants in the North as well as detailed summary tables of data collected. Emphasis was placed on writing the report in "plain language" without trying to jeopardize any scientific concepts or findings. One hundred reports were printed and distributed to all communities, stakeholders and interested parties.

Materials for healthcare workers, participants and communities

- Along with the Regional Report, the following materials were created:
- A "Quick Reference Guide" was created for healthcare workers in the region. This was created after consultation with community health representatives (CHRs), nurses and hospital staff that indicated a need for quick access to information regarding the program and health issues surrounding contaminants. It also served to help them in reading both individual and group results.
- Medical records for all contaminants studied were created for each participant and delivered to the health records department of the Inuvik Regional Hospital, for confidential placement in medical files.

- Individual participant packages were created. The packages were sent to the CHRs in each community, whom in turn, hand delivered the packages to the participants.

Presentations and meetings

- The coordinator presented the background and methods of the program at the Canadian Institute of Public Health Inspectors Educational 2000 Conference, April 2000. The Inuvik Regional Health and Social Services Board sponsored this initiative. It was successful in educating health and environmental professionals about contaminants in the North.
- The project was presented at medical rounds at the Inuvik Regional Hospital. This helped in educating healthcare workers about the program findings and how to answer any questions that may be presented to them.
- The coordinator attended monthly community tele-meetings prior to any results being released (individual or group). The nurses and CHRs in all communities were involved.
- Six community presentations were completed in Inuvik, Sachs Harbour, Deline, Ft. McPherson, Aklavik and Tsiigehtchic. The presentations aimed to educate the community as a whole about contaminants, inform them of the regional results – including comparisons to other regions, discussed why pregnant women participated and suggested ways to reduce exposure. Concerns from individual participants were answered by the local CHR, or the Program Coordinator, in person or over the phone. Generally, the project was presented in conjunction with other health issues being presented by the Health Board. This ensured that active members of the community were present and also attracted a larger turnout. The presentations included a visual PowerPoint presentation, paper handouts, a roundtable discussion (with translators as necessary) and a question-and-answer period.

Results

Results of the information generated through this program have been previously reported in Walker et al. (2000) and Tofflemire (2000).

The activities described above were well received by local communities and medical personnel. The following numbers reflect the education and communication efforts that were received in the Inuvik Region, from April to July 2000:

- Every community in the region (100%) received the regional report and additional educational handouts.
- All CHRs and nurses from every community (100%) received detailed information and guidance regarding the program and plans for results dissemination.
- Presentations occurred in six communities (50%) in the Inuvik Region. The six communities were home to 79% of the women who participated in the study.
- Participant packages were created for all women in the study; however, some participants had migrated to different communities and/or provinces by the end of the study. Efforts were made to find any participant who had relocated. By the end of the study, 89% of participants received personal packages. In the case of a returned package, the personal results were destroyed.

While making community visits, it was noted that the CHRs were especially helpful in disseminating information and generating discussions. The various representatives appreciated being a key part of the project and thus helped with the success of results dissemination. The medical personnel in the Inuvik region were also responsive to being educated about contaminants and the project. Teamwork among various departments at the Inuvik Regional Hospital, the community health centres, and Government of Northwest Territories, Department of Health and Social Services, and local community organizations proved to be invaluable. More discussion can always be carried out in the various communities regarding contaminants issues; this need was noted at the conclusion of this project.

Discussion

Communication of results from research is an important and integral part of the Northern Contaminants Program, and is of great importance for the communities in the Inuvik region. The explanation of data can be difficult and abstract; data must be presented in a contextual manner that answers the questions about which local communities are interested in learning. Most community members found it helpful to discuss the issues, as opposed to only reading the information. Reading and comprehension levels vary among community members. The communities were happy to have an opportunity to learn and voice an opinion on the subject. The women who participated felt pleased that they had made a contribution to the community and appreciated the personal results packages. Most women were content with the information they had received, while others required more discussion concerning their results.

Harvesting, sharing, processing and consuming traditional food are important to cultural identity. Any concerns about contaminants in these foods can affect both the physical and social well-being of people of the North. Traditional foods are nutritious and contain only low amounts of contaminants in the Inuvik region. However, it is important for communities to remain informed about what contaminants are and at what levels they may be of concern. Continuing with monitoring programs in the future will allow us to see if levels of contaminants are changing over time. Education regarding these issues will help local communities make healthy lifestyle choices.

Project Completion Date

July 2000

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Monitoring the Health of Arctic Peoples and Ecosystems and the Effectiveness of International Controls

Part A: Abiotic Monitoring and Modelling

New Persistent Chemicals in the Arctic Environment

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Abstract

This report updates the investigation of new chemicals in the Arctic environment. New chemicals include substances not currently monitored by the Northern Contaminants Program but of potential concern based on known persistence, extent of usage and toxicology. Chemicals in this study include brominated flame retardants, polychlorinated naphthalenes (PCNs), coplanar polychlorinated biphenyls (PCBs), short-chain chloroparaffins (SCCPs), polychlorinated diphenyl ethers (PCDEs), modern agrochemicals, pesticide enantiomers, synthetic musks (artificial fragrances), chlorinated phenols and haloacetic acids.

Air samples collected at Arctic monitoring stations from January 1994 to January 1995 were analyzed for PCNs, coplanar PCBs (mono- and non-*ortho* congeners) and polybrominated diphenyl ethers (PBDEs). Ranges of ΣPCNs and Σcoplanar PCBs ($pg \cdot m^{-3}$) were Alert: 0.11 to 1.03 and 0.03 to 0.19; Dunai: 0.21 to 2.6 and 0.18 to 0.86. Opposite seasonal trends were found for the two compound classes. PCNs were highest in winter, early spring and late fall, and lowest in summer. Coplanar PCBs were elevated in summer and lower in the colder months. PCNs and polycyclic aromatic hydrocarbons show similar seasonality, suggesting that combustion may contribute PCNs to Arctic air. ΣPBDE concentrations ($pg \cdot m^{-3}$) ranged between 7 to 72, 11 to 860 and 42 to 2200 for samples collected at Dunai, Alert and Tagish, respectively.

Relatively high concentrations of PBDEs were observed during the summer months at Tagish. This could be attributed to volatilization of PBDEs from recent local incineration of discarded household/commercial items,

and/or from re-volatilization of PBDEs from the soil in the vicinity of the incineration sites. The source of PBDEs in Tagish area will be further investigated in 2001-2002. Concentrations of SCCPs in the Alert air samples were highest in the late summer months. SCCPs levels (pg·m^{-3}) ranged from 1.07 to 7.25 and were dominated by contributions by the chlorododecanes. The above air samples, and 1998 sets collected in Arctic Finland and at the Swedish west coast, were analyzed for chlordane enantiomers. *Trans*- and *cis*-chlordane were non-racemic in the air samples, but racemic in surface water samples collected from the northern Canada Basin in 1994. Non-racemic chlordanes are commonly found in soils. This suggests that the source of chlordane in Arctic air has changed over time, with a greater proportion of "recycled" chlordane in recent years, whereas seawater under the ice cap retains the signature of older chlordane emissions.

ΣPCNs and Σcoplanar PCBs were determined in blubber of beluga from Pangnirtung and ringed seal from Kimmirut, collected in 1994 and 1993, respectively. PCNs ranged from 40 to 384 pg·g^{-1} in beluga and 29 to 63 pg·g^{-1} in ringed seal; ranges for coplanar PCBs in the two animals were 14 to 394 ng·g^{-1} and 15 to 33 ng·g^{-1}. An assessment of dioxin-like toxic equivalents (TEQs) from these two compound classes showed that, although PCNs were about 500 times less abundant than coplanar PCBs, they contributed 11% of the TEQ. Synthetic musks were determined in ringed seal blubber, Arctic char muscle and blue mussels from the Canadian Arctic, and lake trout from Lake Ontario. All Arctic samples were below the limit of detection (< 1 ng·g^{-1}), except for one seal blubber sample which contained 5 to 12 ng·g^{-1} of the polycyclic musks HHCB and HHCB-lactone, and 5 ng·g^{-1} of musk ketone, a nitro musk. Lake trout samples contained a wider variety of musks and at generally higher levels.

Key Project Messages

1. Polychlorinated naphthalenes (PCNs) at Alert and Dunai were elevated in winter, early spring and late fall, and were lowest in summer. Coplanar polychlorinated biphenyls (PCBs) showed the opposite trend, being higher in late spring through early fall, and lower in winter; they were three times higher at Dunai than Alert. The seasonal differences may reflect a greater contribution of combustion sources for PCNs and evaporative sources for coplanar PCBs.
2. Relatively high levels of polybrominated diphenyl ethers (PBDEs) were observed during the summer months at Tagish compared to Alert and Dunai. This might be due to emissions of PBDEs from local incineration.
3. Short-chain chloroparaffins (SCCPs) at Alert were highest during the late summer months and were dominated by chlorododecanes.
4. Chlordanes in Arctic air have declined over the last 14 years with times for 50% depletion of 6.1 to 7.7 years. Isomer and enantiomer patterns suggest that "older" chlordane is entering the Arctic atmosphere today, likely derived from soil emissions.
5. PCNs occur in beluga and ringed seal blubber at concentrations 500 to 1000 times lower than those of coplanar PCBs. Nevertheless, PCNs in beluga contribute 11% of the dioxin-type toxic equivalents due to the sum of both compound classes.
6. Synthetic musks (perfuming ingredients) were near or below detection limits in ringed seal blubber, Arctic char muscle and blue mussels from northern Quebec and Labrador.

Objectives

1. Determine coplanar PCBs, PCNs, brominated flame retardants, short-chain chlorinated paraffins, modern agrochemicals and enantiomers of selected organochlorine pesticides in archived air samples from Arctic monitoring stations.
2. Search for other "new" chemicals in the Arctic abiotic and biotic environment, not currently monitored by the Northern Contaminants Program (NCP) but of potential concern based on known persistence, extent of usage and toxicology.

Introduction

The rationale for undertaking a study of new chemicals in the Arctic environment was presented in previous reports to the NCP (Bidleman et al. 1999, Muir et al. 1999). "New" chemicals are those which are currently used and/or not presently included in monitoring programs. Substances undergoing investigation in this project include: brominated flame retardants (polybrominated diphenyl ethers [PBDEs], hexabromocyclododecane [HBCDD], decabromobiphenyl and tetrabromobisphenol-A [TBBPA]); industrial chemicals (PCNs, coplanar PCBs (mono- and non-*ortho*-congeners), SCCPs, PCDEs, chlorophenolic compounds]; modern agrochemicals; pesticide enantiomers; synthetic musks; and haloacetic acids (HAAs). PCDEs in beluga were reported previously (Bidleman et al. 1999, Stern and Ikonomou 2000) and are not included here. The research proposed here directly relates to the NCP Blueprint for International Activities, Section 1.3, Other Chemicals of Potential Concern. Certain aspects also contribute to other sections of the Blueprint. Investigation of enantiomers aids in detecting and interpreting trends in relation to emission control strategies by providing a means of distinguishing "recycled" pesticide from new releases.

Information on the occurrence and trends of "new" chemicals in air, water, sediments and biota has been presented in previous reports (Bidleman et al. 1999, Bidleman et al. 2000, Muir et al. 1999, Stern et al. 2000). This report presents an update of results obtained in 2000-2001. Sampling and analytical methods for most media and compounds have been reported previously and are not detailed here unless new.

Activities in 2000-2001

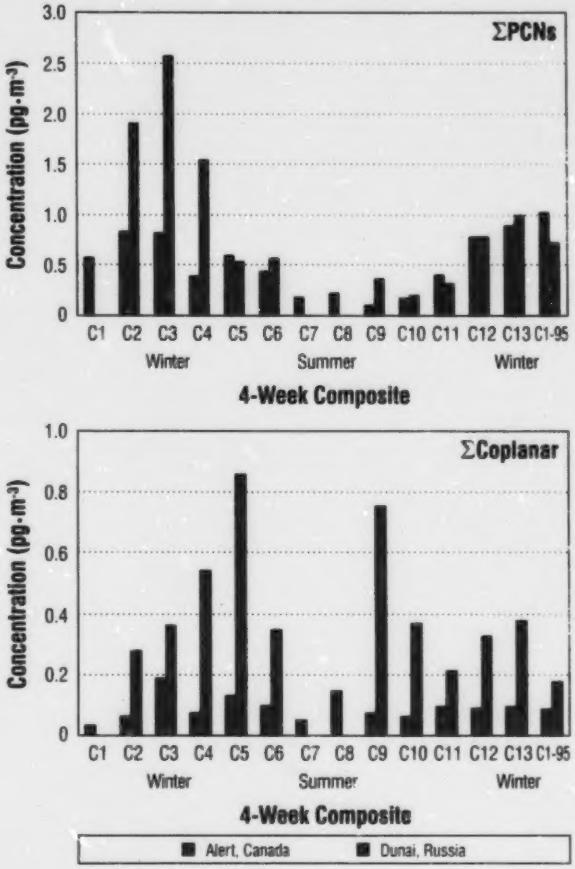
PCNs and coplanar PCBs

Results and discussion: Air

Extracts of archived air samples, both polyurethane foam (PUF) plugs and filters, were analyzed for PCNs and coplanar PCBs using previously described methods (Helm et al. 1999; Harner et al. 1998). The coplanar PCBs consisted of 8 non- and mono-*ortho* substituted PCBs: CB-81, -77, -118, -114, -105, -126, -156 and -169. ΣPCN concentrations, reported last year, ranged from 0.11 to 1.03 pg·m^{-3} at Alert, Nunavut and 0.21 to 2.6 pg·m^{-3} at Dunai Island, Russia. A seasonal trend for ΣPCNs was observed with higher concentrations occurring during the winter/spring months (Figure 1). This is similar to the seasonality observed for polycyclic aromatic hydrocarbons (PAHs) (Halsall et al. 1997), but is quite different from the coplanar PCB trend (see below), and suggests that PCNs, like PAHs, may be combustion-related.

Σcoplanar PCB concentrations averaged 0.09 pg·m^{-3} (range 0.03 to 0.19 pg·m^{-3}) at Alert and 0.42 pg·m^{-3} (range 0.18 to 0.86 pg·m^{-3}) at Dunai Island (Figure 1). Pentachlorobiphenyls 118 and 105 were the dominant congeners at both sites. Seasonal variation was observed at the Dunai Island site with higher coplanar PCB concentrations during the summer months. No trend was evident at Alert. This agrees with the findings of Stern et al. (1997) that the contribution of pentaCB congeners to ΣPCBs increased in summer, particularly at Dunai. The authors suggested that emissions of Russian PCB mixtures with higher percentages of pentaCBs could account for this observation. Stern et al. (1997) found no correlation of ΣPCBs with temperature. This illustrates that northern Eurasian sources continue to contribute planar compounds (PCNs and PCBs) to Arctic regions. The effect of this can be seen in levels of planar PCBs found in marine biota. Higher levels have been found in ringed seal blubber from the Russian Arctic (Nakata et al. 1998) than from the Canadian Arctic (Helm et al. 2001).

Figure 1. Monthly variation in ΣPCNs (top) and Σcoplanar PCBs (bottom) in air at Alert and Dunai from January 1994 to January, 1995 (pg·m^{-3})*



* C1, C2, etc. refer to 28-day composite samples (13 composites in 12 months).

Several PCN congeners have dioxin-like toxicity, as do non- and mono-*ortho* substituted PCBs. The contribution to dioxin toxic equivalents (TEQs) in air samples was calculated for PCNs and coplanar PCBs using relative potencies or toxic equivalency factors determined by HII4E bioassays for both PCNs (Blankenship et al. 2000, Villeneuve et al. 2000, Kannan et al. 2001) and PCBs (Giesy et al., 1997). Average ΣTEQs (sum of PCNs, mono- and non-*ortho* PCBs) were 0.016 fg·m^{-3} at Alert and 0.046 fg·m^{-3} at Dunai. PCNs contributed approximately 55% of TEQs relative to the PCBs in air at both stations.

Results and discussion: Marine mammals

Blubber from beluga whales (*Delphinapterus leucas*) collected in 1994 near Pangnirtung, Nunavut, and from ringed seals (*Phoca hispida*) collected in 1993 near Kimmirut, Nunavut, were analyzed for PCNs and coplanar PCBs (Helm et al. 2001). ΣPCN concentrations were higher in beluga whale blubber, ranging from 40 to 384 pg·g^{-1} (n = 6) than in ringed seal blubber which ranged from 29 to 63 pg·g^{-1} (n = 6), each on a wet weight basis (approximately 90% lipid) (Table 1). The PCN homolog distribution varied between species with a higher proportion of lower chlorinated PCNs found in ringed seal. In the beluga, pentaCNs dominated, followed by hexaCNs and tetraCNs. Many of the hexaCNs are the more toxic PCN congeners. ΣPCN levels were lower in female belugas (n = 3) than in males (n = 3). In ringed seals, no differences related to sex were observed.

Σcoplanar PCB concentrations were much higher than ΣPCN levels in both species, ranging from 14.4 to 294 ng·g^{-1} in beluga whale blubber and 14.9 to 32.7 ng·g^{-1} in ringed seal blubber (Table 1). Again, levels were higher in beluga whale than ringed seal blubber. In both species, CB-118, CB-105 and CB-156 were the most dominant congeners. Coplanar PCB levels were lower in females than males for both ringed seals and beluga whales.

PCNs and coplanar PCBs were compared on a TEQ basis with relative potencies or toxic equivalent factors used in the air calculations. TEQ contributions are listed in Table 1. Although coplanar PCB concentrations are about 500 times greater than PCNs on average in beluga whale blubber, PCNs contributed 11% of the TEQ relative to coplanar PCBs. PCNs may be of similar or greater importance than chlorinated dioxins/furans in some Arctic species on a TEQ basis. In ringed seals, the contribution to TEQ by PCNs was negligible due to lack of the more toxic hexaCN congeners.

Synthetic musks

The synthetic polycyclic musks HHCB (1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[*g*]-2-benzopyrane; e.g. galaxolide®) and AHTN (1-(5,6,7,8-tetrahydro-3,5,5,6,8,8-hexamethyl-2-naphthalenyl)-ethanone; e.g. tonalide®) are important artificial fragrances used in a large number of perfumes, laundry detergents, fabric softeners, toiletry products and other household products. The polycyclic musk ATII (1-[2,3-dihydro-1,1,2,6-tetramethyl-3-(1-methyl-ethyl)-1H-inden-5-yl]-ethanone; e.g. traseolide), the main HHCB-transformation product, 1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[*g*]-2-benzopyrane-1-one (hereafter HHCB-lactone, sometimes referred to as

Table 1. Sex, age, PCN concentrations (pg·g^{-1} wet weight), coplanar PCB concentrations (ng·g^{-1} wet weight), and TEQ (fg·g^{-1} wet weight) for beluga whale samples from Kimmirut, NU, and ringed seal samples from Pangnirtung, NU

				Concentration		TEQ (fg·g^{-1})	
Sample	**Species**	**Sex**	**Age**	**ΣPCNs (pg·g^{-1})[1]**	**ΣCopl. PCBs(ng·g^{-1})[2]**	**ΣPCN[3]**	**ΣCopl. PCBs[4]**
B94-118	Beluga	M	6+	384.1	97.1	215	1992
B94-120	Beluga	M	1+	298.2	125.2	237	1014
B94-122	Beluga	M	1+	342.7	293.8	395	2183
B94-142	Beluga	F	6	229.3	90.4	172	1891
B94-151	Beluga	F	6+	203.8	75.9	129	1792
B94-163	Beluga	F	20+	40.0	14.4	26	269
ARPG93-54	Ringed seal	F	10	56.3	14.9	0.8	425
ARPG93-56	Ringed seal	M	8	41.2	29.8	2.4	723
ARPG93-57	Ringed seal	M	7	47.5	32.7	0.8	689
ARPG93-59	Ringed seal	M	9	43.6	17.6	<0.1	459
ARPG93-60	Ringed seal	F	13+	28.7	16.3	<0.1	601
ARPG93-61	Ringed seal	F	8+	62.5	14.9	<0.1	499

[1] Sum of tri- to hepta-chloronaphthalenes.

[2] Sum of chlorobiphenyls: 77, 81, 105, 126, 118, 114, 156, 169.

[3] Calculated using PCN TEFs/REPs listed in Kannan et al. 2001 and Blankenship et al. 2000. TEF for CN-68 used for coeluting CN-64 and -68 congeners. TEF for CN-60 used for coeluting CN-52 and -60 congeners. Individual REPs used for CN-66 and CN-67.

[4] Calculated using TEFs listed in Giesy et al. 1997.

galaxolidone) as well as the nitro musks musk xylene (MX) and musk ketone (MK) were also included. The stereochemical structures of the three polycyclic musk compounds can be found in Table 2.

Methods

The extraction, clean-up and fractionation procedure was carried out according to the multi-method for polycyclic and nitro musks in fatty fish and human tissue samples described by Rimkus et al. (2001). The method involves cold-extraction by a mixture of water/acetone/petroleum ether, separation from the lipid matrix by GPC followed by a mini-silica column (elution with 10 mL toluene/acetone 95:5). GC/MS was carried out in the SIR-mode (equivalent to SIM) using a high resolution VG 70-250 SE mass spectrometer (VG Analytical, Manchester, U.K.). All compounds were investigated by the analysis of at least two m/z values.

Results and discussion

The concentrations of the polycyclic musks ATII, HHCB and AHTN, the main HHCB-transformation product HHCB-lactone as well as of the nitro musks MX and MK as determined in samples from the Arctic and other Canadian locations are summarized in Table 3.

With the exception of HHCB and HHCB-lactone, musk concentrations were less than the limit of detection (LOD) or the background levels (based on butterfat) in all Arctic samples but were detectable in check samples of Lake Ontario lake trout (whole fish).

Table 2. Chemical names, abbreviations and structures of musk compounds

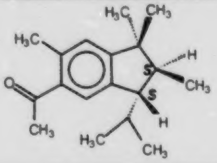
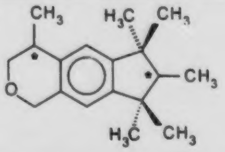
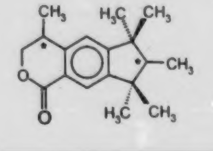
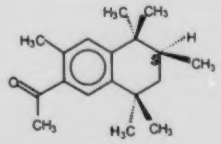
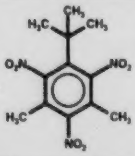
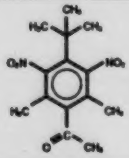
Chemical Name	Abbreviation	Chemical Structure
1-[2,3-dihydro-1,1,2,6-tetramethyl-3-(1-methyl-ethyl)-1H-inden-5-yl]-ethanone (e.g. traseolide)	ATII	
1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[g]-2-benzopyrane (e.g. galaxolide®)	HHCB	
1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[g]-2-benzopyrane-1-one ("galaxolidone")	HHCB-lactone	
1-(5,6,7,8-tetrahydro-3,5,5,6,8,8-hexamethyl-2-naphthalenyl)-ethanone (e.g. tonalide®)	AHTN	
1-tert-butyl-3,5-dimethyl-2,4,6-trinitrobenzene (musk xylene)	MX	
1-(4-tert-butyl-2,6-dimethyl-3,5-dinitrophenyl)ethanone (musk ketone)	MK	

Table 3. Concentrations of synthetic musks (ng·g^{-1} wet wt) in Canadian Arctic and control samples

Samples	Location	ATII	HHCB	HHCB-Lactone	MX	MK
Ringed seal (blubber)	Nain	nd[1]	5	12	< LOD	5
Ringed seal (blubber)	Nain	< LOD[2]	< LOD	< LOD	< LOD	< LOD
Ringed seal (blubber)	Nain	< LOD	< LOD	< LOD	< LOD	< LOD
Arctic char – muscle[3]	Nain	nd	nd	nd	< LOD	< LOQ[4]
Blue mussels	Quaqtaq	nd	nd	nd	nd	nd
Blue mussels	George River	nd	nd	nd	nd	nd
Lake Trout (Lake Ontario)	17 320	6	60	135	7	< LOQ
Lake Trout (Lake Ontario)	17 323	6	25	59	3	3
Butterfat (for blank determination)	Blank 1	nd	24	6	< LOD	< LOD
Butterfat (for blank determination)	Blank 2	nd	22	12	< LOD	2

[1] Not detectable: Nothing can be detected at that specific m/z ; < 1 ng·g^{-1} or lower for all compounds.

[2] < Limit of detection: Something can be detected at that specific m/z, however, a potential coelution cannot be excluded ; < 5 ng·g^{-1} approximately, for all compounds.

[3] Pool of six char samples from Nain, Labrador: NC-1, NC-4, NC-5, NC-6, NC-8.

[4] < Limit of quantification: The target compound can be detected, however, a signal:noise ratio < 9:1 was encountered; < 5 ng·g^{-1} approximately, for all compounds.

HHCB and HHCB-lactone were above detection limits in one ringed seal sample only (out of three samples analyzed); the concentration of the metabolite exceeded that of the parent compound by more than a factor of two. However, results were near concentrations in butterfat which was used as a control sample. The inverse ratios of the HHCB/HHCB-lactone may be an indication that metabolism of HHCB occurs in the ringed seal. However, improved methods with lower background values will be required to verify this conjecture.

The HHCB and MX values in the lake trout samples are similar to those of a previous study (Gatermann et al. 1999), while, by contrast, the concentrations for MK are significantly lower than reported previously. This may be because of laboratory contamination which is a major concern in the analysis of musks. Furthermore, it is interesting to note that the HHCB-lactone concentrations exceed those of the parent compound HHCB by more than a factor of two. This result is in accordance with concentrations of HHCB and HHCB-lactone determined in liver extracts from Atlantic cod (*Gadus morhua*) caught in the Oslofjord region of southern Norway (Gatermann and Kallenborn 2001).

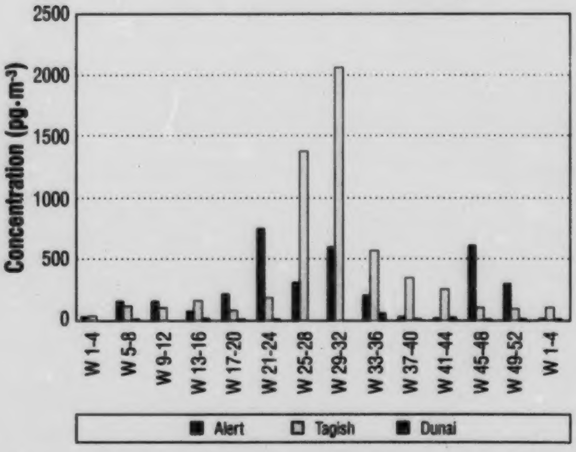
PBDEs

Archived air samples (116 PUF, filter, and blanks) from the Arctic air monitoring stations Tagish, Alert and Dunai were analyzed for PBDEs. These samples represented composites of four weekly samples (i.e. weeks 1 to 4, 4 to 8, etc.) from January 1994 to January 1995. The PBDEs were determined by HRGC/HRMS as described previously (Bidleman et al. 1999).

Results and discussion

Concentrations of ΣPBDEs in air samples from Alert, Dunai and Tagish are presented in Figure 2, and levels for selected BDE congeners are reported in Table 4. The distributions of four PBDEs between the particle and gas phases are shown in Figure 3. The levels of PBDEs in air samples from Dunai were the lowest among the three sites. The concentrations of PBDEs in air samples from Alert were lower than air samples from Tagish. Relatively high levels of mono- to hepta-BDEs were detected at Tagish with maximum concentrations occurring during

Figure 2. Total mono- to hepta-BDEs in air (PUFs and filters) in archived air sample extracts, from Tagish, Alert and Dunai 1994-1995 (pg·m^{-3})*



* Labels on horizontal axis refer to 28-day composite samples.

the summer months (Figure 2). Air temperatures at Tagish were much higher compared to Alert and Dunai. The PBDE values at Tagish are higher than air concentrations reported by Dodder et al. (2000) for the city of Chicago, which indicates the possibility of incineration of household items in the vicinity of the sampling site. The high levels of PBDEs in air samples from Tagish can be from incineration events during the summer months, or may be the results of vapourisation from the soil in the vicinity of the incineration site(s). The main PBDE congeners observed in these samples were BDE-47, -99, -100, -153 and -154. As shown in Table 4, BDE-99 has the highest concentration followed by BDE-47, -100, -153 and -154. The pattern in these samples resembles the commercial products, rather than the pattern reported by Bergander et al. (1995) from two sampling sites in Sweden and by Dodder et al. (2000) in samples from the Great Lakes area. Another interesting feature in the samples collected at Alert is the presence of mono-, di- and tri-BDE congeners, which is an indication of photodegradation of PBDEs during long-range atmospheric transport. It is important to note that field blanks showed varying levels of the PBDEs. BDE congeners 47 (2,4,2',4'-tetra) and 99 (2,4,2',4',5'-penta) were the major congeners in both PUFs and filters. To resolve a number of issues, additional samples will be analyzed during 2001-2002. These samples include additional blanks to better estimate contributions from blanks, along with weekly samples to better understand the sources of PBDEs in samples collected in Tagish.

Short chain chloroparaffins (SCCPs)

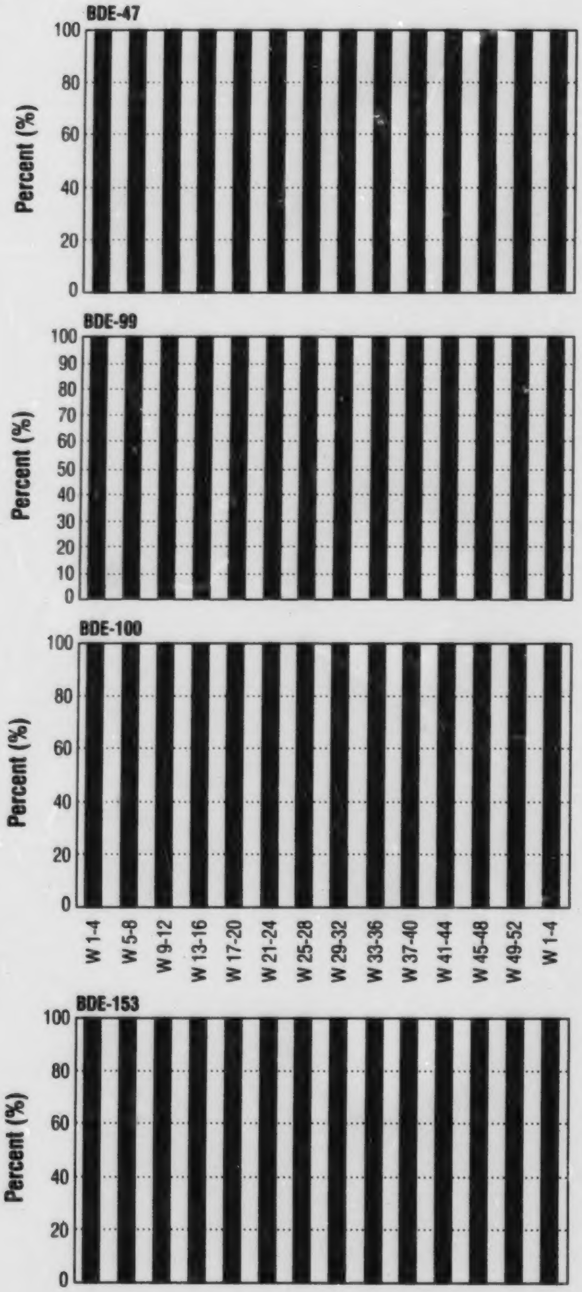
Archived air samples (13 PUF, filter, and blanks) from Alert were analyzed for SCCPs. These samples represented composites of 4 weekly samples (i.e. weeks 1 to 4, 4 to 8, etc.) from January 1994 to January 1995. The SCCPs were

Table 4. Concentration of selected PBDE congeners in monthly composite atmospheric samples from the Arctic[1]

Week #	BDE-47	BDE-99	BDE-100	BDE-153	BDE-154
Tagish					
W 1-4	5.5E+00	1.3E+01	3.4E+00	2.6E+00	2.0E+00
W 5-8	8.9E+00	5.8E+01	1.7E+01	1.6E+01	1.2E+01
W 9-12	3.6E+01	5.1E+01	1.1E+01	8.9E+00	6.0E+00
W 13-16	6.5E+01	7.3E+01	1.5E+01	7.7E+00	4.8E+00
W 17-20	4.0E+01	3.3E+01	6.8E+00	2.5E+00	2.1E+00
W 21-24	8.1E+01	7.8E+01	1.5E+01	5.5E+00	4.7E+00
W 25-28	4.4E+02	7.8E+02	1.2E+02	6.0E+01	4.5E+01
W 29-32	5.4E+02	1.2E+03	1.7E+02	1.4E+02	7.7E+01
W 33-36	1.6E+02	3.3E+02	4.7E+01	4.9E+01	2.2E+01
W 37-40	7.9E+01	2.1E+02	2.9E+01	3.6E+01	1.7E+01
W 41-44	5.7E+01	1.7E+02	2.0E+01	2.9E+01	1.2E+01
W 45-48	2.1E+01	8.7E+01	9.8E+00	1.4E+01	6.7E+00
W 49-52	1.8E+01	7.9E+01	9.0E+00	1.9E+01	7.5E+00
W 1-4	2.1E+01	8.7E+01	1.0E+01	1.8E+01	7.9E+00
Alert					
W 1-4	5.2E+00	2.1E+01	4.7E+00	3.6E+00	2.5E+00
W 5-8	2.3E+01	8.9E+01	1.8E+01	1.4E+01	1.1E+01
W 9-12	1.5E+01	8.1E+01	1.8E+01	1.9E+01	1.2E+01
W 13-16	2.0E+01	9.9E+01	1.2E+01	6.4E+00	5.1E+00
W 17-20	1.2E+01	1.1E+02	1.0E+01	3.4E+01	1.6E+01
W 21-24	1.6E+02	4.2E+02	5.4E+01	5.9E+01	3.3E+01
W 25-28	6.5E+01	1.5E+02	2.5E+01	3.1E+01	1.2E+01
W 29-32	2.5E+02	2.7E+02	6.3E+01	1.5E+01	1.4E+01
W 33-36	5.2E+01	1.2E+02	2.4E+01	9.9E+00	8.4E+00
W 37-40	6.8E+00	2.0E+01	3.7E+00	3.1E+00	1.9E+00
W 41-44	5.5E+00	1.1E+01	2.0E+00	1.5E+00	1.0E+00
W 45-48	1.8E+02	2.6E+02	3.8E+01	2.8E+01	1.7E+01
W 49-52	9.7E+01	1.4E+02	2.5E+01	1.2E+01	7.3E+00
W 1-4	3.4E+00	5.3E+00	8.5E-01	5.3E-01	3.1E-01
Dunai					
W 1-4					
W 5-8	2.6E+00	7.1E+00	1.7E+00	1.9E+00	
W 9-12	1.7E+00	3.2E+00	7.2E-01	2.5E-01	
W 13-16	3.4E+00	4.6E+00	1.0E+00	3.3E-01	
W 17-20	2.8E+00	2.9E+00	9.4E-01	2.7E-01	
W 21-24	3.8E+00	3.1E+00	1.1E+00	2.6E-01	
W 25-28					
W 29-32					
W 33-36	9.2E+00	3.4E+01	1.1E+01	7.4E+00	
W 37-40	5.2E+00	1.2E+01	3.4E+00	2.5E+00	
W 41-44	5.2E+00	1.9E+01	5.8E+00	4.4E+00	
W 45-48	2.2E+00	7.3E+00	2.4E+00	1.7E+00	
W 49-52	2.3E+00	4.7E+00	1.3E+00	6.6E-01	
W 1-4	2.2E+00	4.5E+00	9.6E-01	5.7E-01	

[1] All values are in pg·m⁻³.

Figure 3. Distribution of selected PBDE congeners between vapour and particle phases for air samples collected at Tagish*



* Distribution in vapour and particulate phases are presented in black and white respectively. Labels on horizontal axis refer to 28-day composite samples.

determined by HRGC/HRMS as described previously (Tomy et al. 1997).

Results and discussion

Blank corrected concentrations of SCCPs of individual carbon chain lengths, as well as total SCCPs, in the Alert PUF air samples are shown in Table 5. SCCPs were only observed in samples from the summer months, and were highest in August. Individual homologue concentrations indicated that the chlorododecanes (C_{12}), accounted for ~ 50% of the total, the bulk being from the hexa- and hepta-chlorododecanes. Non-detectable levels of SCCPs were found in PUFs for periods other than summer months and also in all the filters.

Chlordane isomers and enantiomers

From 1984 to the present, *trans*-chlordane, *cis*-chlordane and *trans*-nonachlor (TC, CC, and TN) have been quantified in several Arctic locations by various workers. Hung et al. (2001) analyzed the time trends of chlordane measurements from 1993-1998 at the Alert station and concluded that chlordanes are declining, with times for 50% reduction ($t_{1/2}$) of 8.3 to 9.6 years for TC, 4.1 to 4.8 years for CC and 6.2 to 8.1 years for TN. Chlordanes in air at Great Lakes monitoring stations showed downward trends from 1992-1995 with $t_{1/2}$ of 3.2 to 6.9 years for TC, 5.9 to 23 years for CC and 5.0 to 33 years for TN (Cortes et al. 1998).

We compiled a record of chlordane measurements in Arctic air from 1984-1997, based on literature reports and recent data from monitoring stations at Alert, Tagish and Dunai. In addition, concentration data from the AMAP station at Pallas, Finland, during 1996-1997 were kindly supplied by E. Brorström-Lundén (Swedish Environmental Research Institute) and S. Juntto (Finnish Meteorological Institute). The data set contains about 500 measurements,

Table 5. Concentrations ($pg{\cdot}m^{-3}$) of SCCPs in Alert air (PUFs) samples[1]

Sample	C_{10}	C_{11}	C_{12}	C_{13}	Total
AA-94-C4-P1 (Apr. 95)	0.12	0.34	0.54	0.07	1.07
AA-94-C5-P1 (May 95)	0.26	0.72	1.14	0.15	2.27
AA-94-C6-P1 (June 95)	0.35	0.98	1.56	0.20	3.09
AA-94-C7-P1 (July 95)	0.49	1.4	2.21	0.29	4.39
AA-94-C8-P1 (Aug. 95)	0.82	2.31	3.65	0.47	7.25
AA-94-C9-P1 (Sept. 95)	0.69	1.95	3.10	0.40	6.14

[1] Non-detectable levels of SCCPs were found in PUFs for periods other than summer months and also in all the filters.

70% from 1993-1997 and 30% from earlier. Concentration data were divided into winter-spring (November to April) and summer-fall (May to October) periods and analyzed by simple linear regression of ln (TC + CC) vs. year (first order plot). The fraction of TC = F_{TC} = TC/(TC + CC) was also plotted vs. year to examine long-term changes in isomer proportions.

Chlordane enantiomers in air samples from the Arctic stations at Alert and Dunai (mostly 1994-1995, with a few from 1993 and 1996; Pallas 1998), and the temperate station at Rörvik on the Swedish west coast were determined as an indicator of historical residue emissions, since non-racemic chlordanes have been found in soils (Aigner et al. 1998, Jantunen et al. 2000, Meijer et al. 2001, Wiberg et al. 2001) and in ambient air from the Great Lakes region (Bidleman et al. 1998, Ulrich and Hites 1998). The samples from Alert and Dunai were mostly monthly composites of archived weekly extracts (see PCN section above) with a few additional individual weekly samples. Those from Pallas and Rörvik were 7-day samples collected once per month. Enantiomers were determined using published methods (Bidleman et al. 1998).

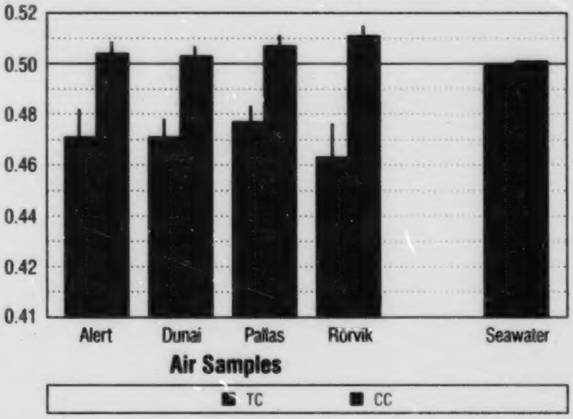
Results and Discussion

Regressions showed significant declines of ln (TC + CC) over the 14-year period in both seasons ($p < 0.001$) (Table 6). Apparent values of $t_{1/2}$ were 7.7 years in winter-spring and 6.1 years in summer to fall, similar to the time trends found by Hung et al. (2001) for the 1993-1997 period. Many years of observation indicates that the ratio of TC/CC undergoes seasonal cycles in Arctic air, higher in winter to spring and lower in summer to fall (Bidleman 1999, Halsall et al. 1998, Hung et al. 2001).

Between 1984-1997, F_{TC} declined significantly in both winter to spring ($p < 0.002$) and summer-fall ($p < 0.03$) seasons (Table 6). This suggests that sources of chlordane in Arctic air have changed over the last 14 years and are now depleted in TC. The F_{TC} in technical chlordane is 0.54, and when weighed for the slightly higher vapour pressure of TC, the expected atmospheric F_{TC} in equilibrium with technical chlordane is 0.62 (Jantunen et al. 2000). The F_{TC} in soils is about the same or lower than in technical chlordane (Aigner et al. 1998, Jantunen et al. 2000, Mattina et al. 1999). Confounding the interpretation of F_{TC} values is the fact that technical heptachlor was also used in agriculture and as a termiticide. Technical heptachlor is contaminated with chlordane isomers, especially TC, so higher F_{TC} in soils or air could be associated with this source. Indeed, Hung et al. (2001) identified occasional spikes of high F_{TC} in Arctic air samples during 1995 and associated them with transport events from Russia. A number of these events also showed elevated heptachlor levels.

Results of the enantiomer analysis are shown in Figure 4. Depletion of the (+)TC and (–)CC enantiomers was found for many of the samples. The average enantiomer fraction, EF = (+)/[(+) + (–)], of TC was significantly non-racemic (racemic EF = 0.500) at all three Arctic stations and the temperate coastal station Rörvik ($p < 0.001$). The average

Figure 4. Enantiomer fractions, EF = (+)/[(+) + (–)], of *trans*-chlordane (TC) and *cis*-chlordane (CC) in air at three Arctic stations (Alert, Dunai, Pallas) and at Rörvik on the Swedish west coast*



* Standard deviations are indicated by vertical bars. See text for sampling periods. EF values for seawater in the northern Canada basin are from Jantunen and Bidleman 1998.

Table 6. Regression statistics for ln (TC+CC), fg·m^{-3} and F_{TC} vs. year (1984 = 0)

	Slope, m	*p*	Intercept, b	r^2	n
Summer-Fall					
Ln (TC + CC) = m*year + b	–0.1144	0	8.526	0.565	20
F_{TC} = m*year + b	–0.00744	0.0293	0.3638	0.237	20
Winter- Spring					
Ln (TC + CC) = m*year + b	–0.0905	0.00011	8.062	0.669	16
F_{TC} = m*year + b	–0.00934	0.00103	0.4774	0.548	16

EFs of CC were also significantly non-racemic, although more so at Pallas and Rörvik ($p < 0.001$) than at Alert ($p < 0.01$) or Dunai ($p < 0.05$). At Alert, the EF of TC was positively correlated with F_{TC} ($r^2 = 0.41$, $p = 0.0032$) (Figure 4). The correlation was not significant at Dunai ($r^2 = 0.0024$, $p > 0.9$), although the July and August data were not available due to lack of samples.

EFs of the octachlordane compound MC5 were determined in six Pallas and seven Rörvik samples. Nearly all were non-racemic, with depletion of the first-eluting enantiomer, except for two Pallas samples in February and March. The average EFs were significantly non-racemic at Pallas (0.487, $p < 0.05$) and Rörvik (0.472, $p < 0.001$). Enantiomers of heptachlor exo-epoxide (HEPX) were determined in four to eight samples from each station and results showed strong enrichment of the (+) enantiomer in all cases (average EFs: Alert = 0.684, Dunai = 0.663, Pallas = 0.665, Rörvik = 0.696).

The non-racemic chlordanes and HEPX in Arctic air provides evidence that soil-derived pesticides are revolatilizing in warmer regions of the Northern Hemisphere and undergoing long-range atmospheric transport. Have chlordanes in Arctic air always been non-racemic, even in the mid-1980s and earlier? This is difficult to answer because no air samples from the 1980s are available for examination. However, chlordanes in surface water collected from the northern Canada Basin collected in 1994 were racemic (EFs = 0.499 for TC and 0.501 for CC). HEPX in seawater was non-racemic with an average EF = 0.639. Most of these samples were collected between 72° to 90° latitude and under ice cover. Chlordane and HEPX EFs in Arctic cod (*Boreogadus saida*), which feed on zooplankton, are similar to those in water (Wiberg et al., 2000). It is likely that these enantiomer signatures represent chlordane and HEPX loadings to the Arctic Ocean sometime in the past.

Expected Project Completion Date

March 2002

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Northern Contaminants Air Monitoring and Interpretation

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Abstract

Atmospheric measurements of organochlorines and polycyclic aromatic hydrocarbons (PAHs) have been conducted at Alert, Nunavut, since 1992. In this study, temporal trends of atmospheric polychlorinated biphenyls (PCBs) and organochlorine pesticides from 1993 to 1997 have been examined. Declining trends were observed for several of the lower PCB congeners reflecting falling levels in source regions and subsequently less material being subject to long-range transport to Alert. No apparent trends were observed for the higher congeners in contrast to southern measurements, except for PCB 180, indicating a lag time for rates of decline between the Arctic and source regions. Most organochlorine pesticides manifested declining trends except the current-use pesticides, such as endosulfan I. From the time series of *trans-/cis*-chlordane ratios, heptachlor and back trajectory analysis, it can be inferred that sporadic uses of technical chlordane and/or heptachlor in eastern and western Russia and Europe/ North Atlantic might have resulted in fresh input into the Arctic atmosphere between 1995 and 1997.

Key Project Messages

1. Some organochlorine (OC) contaminants decreased in the Arctic atmosphere between 1993 and 1997, although more slowly than at sites around the Great Lakes.
2. Current-use pesticides remained constant or increased.
3. Specific chemical signatures coupled with air mass origin can be used to infer geographical areas responsible for pesticide usage.
4. The Arctic atmosphere is still strongly influenced by long-range transport of chemicals from the south and is acting as a sink for OC contaminants.

Objectives

1. Measure and understand the occurrence and trends of selected OCs and polycyclic aromatic hydrocarbons (PAHs) in the Arctic atmosphere to determine whether concentrations are changing in response to national and international initiatives.

2. Provide insight into contaminant pathways (sources, transport, transformation and removal processes) to the Arctic environment.
3. Enable validation of models of toxic chemicals in the Arctic environment with atmospheric observations.
4. Operate a major long-term trends measurement station at Alert, Nunavut (in operation since 1992) in parallel with an eastern Arctic site (Kinngait) and a western Russian Arctic station to contribute to the next assessments by the Northern Contaminants Program and the Arctic Monitoring and Assessment Programme, and to advise Canadian negotiators in preparing contaminant control strategies.

Introduction

Atmospheric measurements of persistent organic pollutants, including herbicides, pesticides, synthetic industrial compounds and PAHs, have been made on a weekly basis in the Canadian (Alert, Tagish, Kinngait [Cape Dorset]) and Russian Arctic (Dunai, Amderma) since January 1992. These measurements are essential since there has been growing concern about contamination of the Arctic environment by OCs and PAHs, whose environmental persistence and fate are influenced by a diversity of physical-chemical properties. Long-term time series will help to determine whether the atmospheric concentrations and deposition of priority pollutants in the Arctic is increasing or decreasing in response to various national and international control initiatives.

Activities in 2000-2001

Regular weekly atmospheric measurements of OCs and PAHs continued at Alert. This involved the collection, extraction and analysis of air samples. The site of Kinngait was re-activated in October 2000 to quantify the change in the eastern Canadian Arctic by comparison with observations made four years earlier. Similar measurements were conducted at Amderma, Russia, with co-support from the Canadian International Development Agency, Department of Indian Affairs and Northern Development, Northern Contaminants Program and MSC.

Data analysis has been progressing well with the recent publication of a paper describing PCB trends at Alert (Hung et al. 2001a) and the submission of a companion paper on OC pesticides trends (Hung et al. 2001b). Results from these two publications are outlined below.

Results

Figure 1 shows the seasonal cycles and trends of PCB congeners 31, 101, 138 and 180 at Alert, determined by the digital filter (DF) trend analysis technique (Nakazawa et al. 1997). By comparing the trends, it was noted that the lower chlorinated congeners, such as PCB 28 (not shown), 31 and 52 (not shown), declined from 1993 to 1997. In each case, both the seasonal minimum and maximum declined over the 5 years. However, no clear trend was apparent for most of the penta- and hexa-chlorinated congeners, such as PCB 105, 118, 138 and 153 (PCB 138 is shown as an example in Figure 1). First order half-lives ($t_{1/2}$) were estimated using the linear regression slopes (***m***) of the DF trend lines:

$$t_{1/2} = \frac{\ln 2}{m}$$

For the PCBs, no pattern was apparent between half-lives and the degree of chlorination, with half-lives ranging from 3 to 17 years. The half-lives at Alert were typically longer than those derived from temperate background/ rural sites from the early 1990s (Simcik et al. 1999).

Figure 2 shows the seasonal cycles and trends of selected OCs at Alert and the weekly average temperature recorded at the sampling site. Most of the selected OCs showed declining trends over the 5 years, except dieldrin and endosulfan I. The *trans-/cis*-chlordane ratio (TC/CC) increased above unity on various occasions (Figure 3). These increases were coincident to periods when the levels of heptachlor were unusually high.

Discussion and Conclusions

PCBs

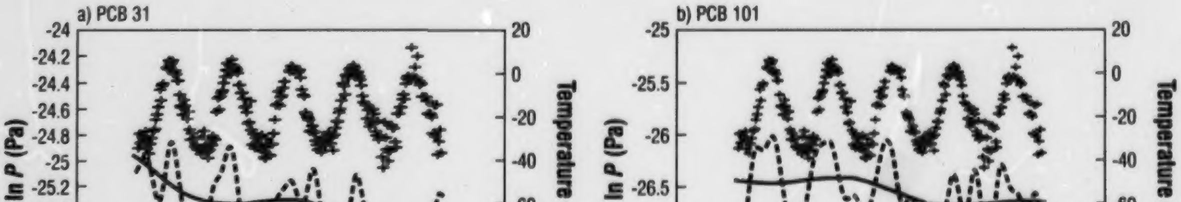
From Figure 1, it can be seen that levels of some of the lower chlorinated congeners do appear to be dropping in the Arctic atmosphere, albeit at a slower rate (i.e. longer half-lives) than temperate studies. This trend for the lighter congeners is probably due to the dominating effect of long-range transport whereby levels in the Arctic will simply reflect the falling levels encountered in the source regions. This, in combination with their relatively fast hydroxyl radical (OH) depletion rates during the Arctic summer, may explain the temporal decline of the lighter congeners. The lack of a declining PCB temporal trend for the more chlorinated congeners may be due to several factors. The lower temperatures encountered in the Arctic, coupled with winter darkness, will slow both biotic and abiotic degradation relative to temperate regions. Importantly, global fractionation (Wania and Mackay 1996) – a process by which chemicals may be latitudinally 'fractionated' according to the ambient temperature and their physical-chemical properties – may have the effect of maintaining Arctic air concentrations, while levels in temperate regions are showing apparent reductions. However, the picture is complicated by notable exceptions; for example, PCB 180 (heptachlorinated) shows a clear downward trend and has a calculated half-life of only 4 years at Alert (compared to 17 years for PCB 153, which showed an almost constant level over the 5 years of study). It is possible that heavier congeners might be subject to different removal processes than the lighter ones. Precipitation or scavenging processes (e.g. particulate deposition and snow scavenging) might be more important for the heavier congeners, while degradation via reaction with OH radicals was the dominant process for the removal of lighter congeners.

OC pesticides

Elevated concentrations of OC pesticides were generally observed before and after the warmest time of the year (Figure 2). This pattern is especially apparent for "current-use" pesticides, such as the HCHs and endosulfan I, and indicates that the atmosphere at Alert was mainly influenced by long-range transport and results of application patterns at temperate locations. Most of the banned OCs showed declining trends over the five years and the half-lives measured in the Arctic were generally longer than at temperate locations. This is probably due to slower transformation processes at lower temperatures in the Arctic, as well as the general lack of air mass movement out of the Arctic environment, especially during winter when air originating from the strong Siberian anticyclone curves eastwards around the Arctic region (Barrie et al. 1992) making dissipation difficult.

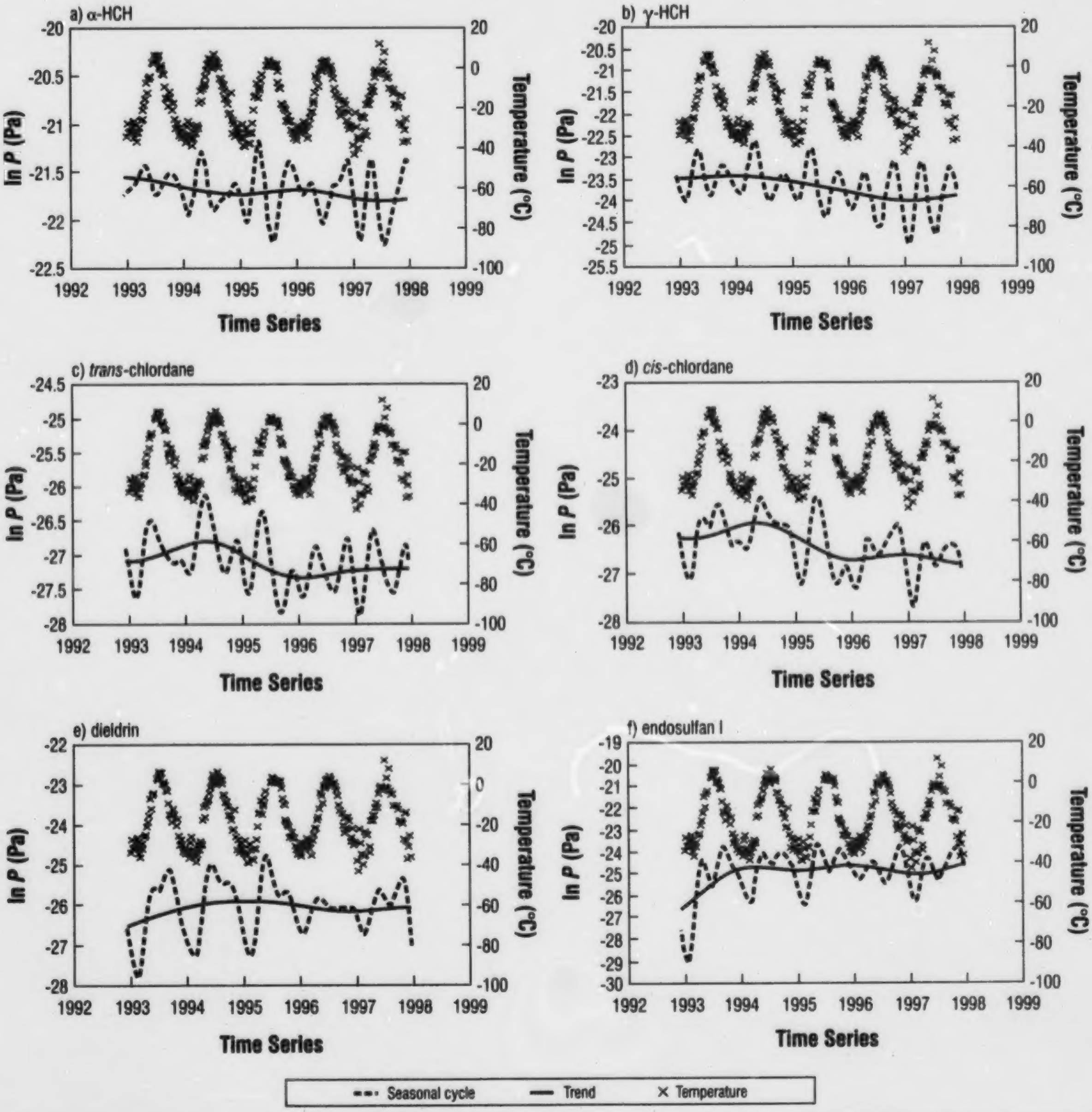
The half-life of *cis*-chlordane was very short compared to *trans*-chlordane. This seems improbable because the *trans*-isomer is less stable than the *cis*-isomer. A hint of why this should occur might be found by examination of the TC/CC ratio. The technical mixture used in the U.S. contains TC/CC in the range of 1.26 to 1.35 (Arctic Monitoring and Assessment Programme 1998). The ratios in the Arctic atmosphere were generally < 1 in recent years (Oehme et al. 1996, Arctic Monitoring and

Figure 1. Seasonal cycle and trends of PCB 31, 101, 138, 180 at Alert



Assessment Programme 1998). This indicates a more weathered chlordane profile when the *trans*-isomer was preferentially photo-transformed. Figure 3 shows the time series of the TC/CC ratio. As can be seen, TC/CC increased above unity on various occasions, especially in the winters between 1995 and 1996, and between 1996 and 1997. Back trajectories for those periods, when TC/CC ratios were > 1, were assigned to geographical sectors. The frequency distribution of trajectories (calculated according to Olsen et al. 1978) to each sector for the periods during which TC/CC > 1 are summarized in Figure 4. Worthy et al. (1999) have shown that, on average, Alert was almost equally affected by air from Northern Canada (Sector 1, 25.9%), the Pacific region (Sector 2, 23.7%), Eastern Russia (Sector 3, 21.0%) and North Atlantic/Greenland (Sector 6, 18.5%) between January 1988 and December 1997. In the weeks covered for the trajectory analysis in this study, when TC/CC > 1, there was a definite shift of air mass movement from the easterly sectors, effectively covering the Eurasia

Figure 2. Seasonal cycles and trends at Alert of a) α-HCH, b) γ-HCH, c) t-chlordane, d) c-chlordane, e) dieldrin and f) endosulfan I



landmass (Figure 4). Although this is a huge region, and, therefore, it is not possible to distinguish actual source areas, it does suggest that for many of the weeks (where TC/CC > 1) the air originated from the Eurasian side of the Arctic as opposed to the North American continent. The high TC/CC ratios observed during these weeks may reflect the influence of a source area(s) where relatively recent chlordane usage has occurred.

Also plotted on Figure 3 are the concentrations of heptachlor measured. The concentrations of heptachlor, a past-used pesticide, were usually very low and mostly below detection limit. However, around those periods when the TC/CC ratios were high, the concentrations of heptachlor were also unusually high. There seems to be new supply of heptachlor into the Arctic air during the winters of 1995-1996 and 1996-1997, coincident with TC/CC > 1. Based on global import figures (United Nations Environment Programme 1996), it is possible that there was indeed fresh input into the Arctic atmosphere. Technical chlordane mixtures usually contain some heptachlor (~ 7 %) (Gooch et al. 1990). When the TC/CC peaked together with heptachlor, it could suggest fresh usage of chlordane mixtures as well.

In summary, some PCBs (lower chlorinated congeners) and most of the OCs (except current-use pesticides) monitored at Alert have shown declining trends over the five years of study, albeit at slower rates than in temperate regions. The Arctic atmosphere is still strongly influenced by long-range transport and acts as a sink for both OC pesticides and PCBs. It is thus important to continue the atmospheric measurements of these compounds at Alert. The measurements taken between 2000-2002 at Kinngait will allow detection of change in the eastern Arctic by comparison with observations made 4 years earlier (1994-1996) at this site.

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Figure 3. ***trans-/cis*-chlordane ratios and heptachlor concentrations**

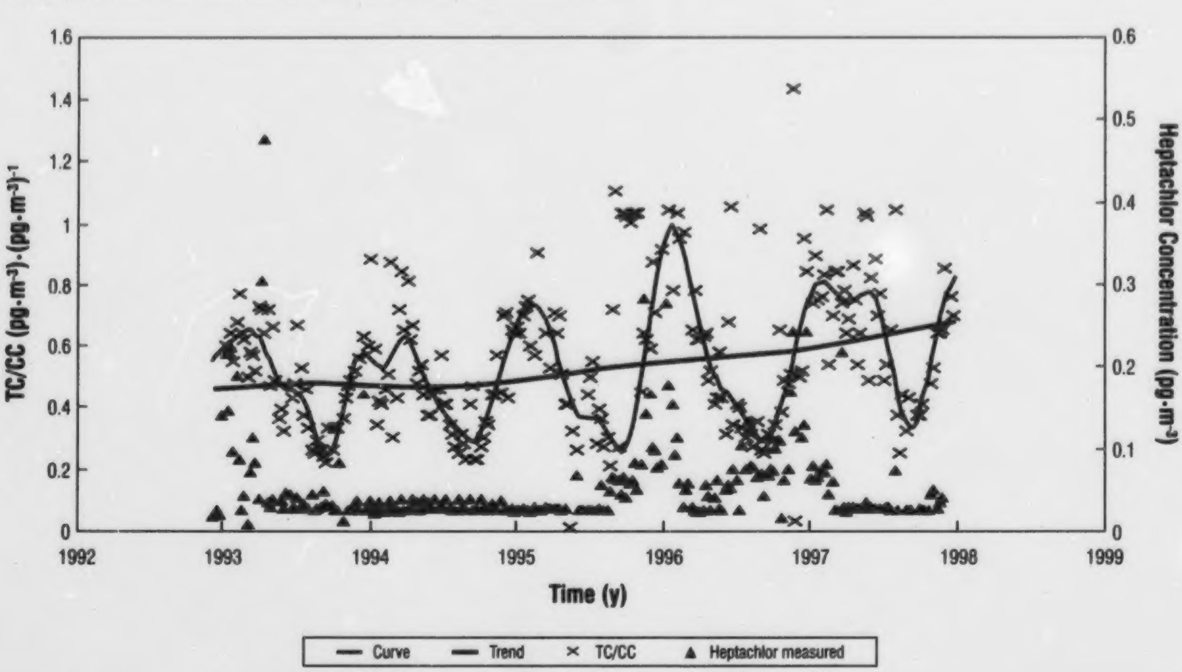
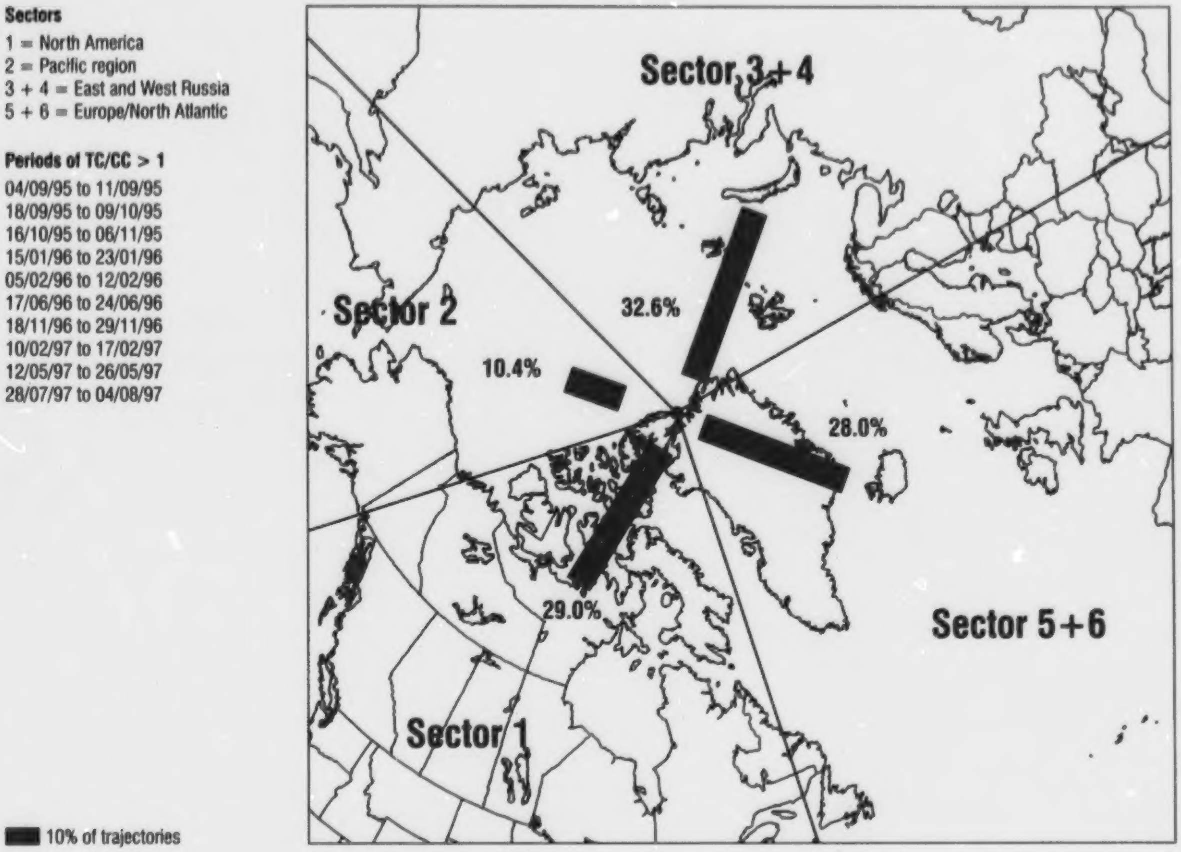


Figure 4. Frequency distribution of back trajectories when TC/CC > 1


Sectors
1 = North America
2 = Pacific region
3 + 4 = East and West Russia
5 + 6 = Europe/North Atlantic
Periods of TC/CC > 1
04/09/95 to 11/09/95
18/09/95 to 09/10/95
16/10/95 to 06/11/95
15/01/96 to 23/01/96
05/02/96 to 12/02/96
17/06/96 to 24/06/96
18/11/96 to 29/11/96
10/02/97 to 17/02/97
12/05/97 to 26/05/97
28/07/97 to 04/08/97
▬ 10% of trajectories
Sector 3+4
Sector 2
32.6%
10.4%
28.0%
29.0%
Sector 5+6
Sector 1

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Spatial Trends in Loadings and Historical Inputs of Mercury Inferred from Arctic Lake Sediment Cores

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Abstract

Historical deposition and fluxes of mercury (Hg) were studied on five sediment cores. The cores were collected from northern Nunavut (Lake Baird Inlet and Lake AXAJ), central Northwest Territories (Lake Rummy and Lake TK-54) and northern Quebec (Lake Oksana). The Hg, iron (Fe) and manganese (Mn) data were assessed as a whole in regards to the co-movement of Hg with Fe and Mn during diagenesis. To date, our data indicate no redistribution or co-movement of Hg with Fe and Mn after deposition at the sediment surface, i.e. the Hg depth profiles truly represent the historical deposition of Hg onto the sediment. Recent Hg fluxes are higher than pre-industrial fluxes, resulting in a range of enrichment factors of 1.2 to 2.7, which are in general agreement with those reported by Lockhart et al. (1998, 2000a) in other parts of the Canadian Arctic. Surprisingly, the lead (Pb) profiles for the lakes in Nunavut and the Northwest Territories show no maxima corresponding to the use of leaded gasoline, as opposed to Lake Oksana, which showed a maximum matching the maximum use of alkyl Pb used in fuel.

Key Project Messages

1. Recent mercury (Hg) fluxes are higher than the pre-industrial fluxes.
2. The Hg enrichment factors range from 1.2 to 2.7.
3. A definite Hg deposition pattern is not yet obvious in Canada's North.

Objectives

1. To determine the depth profiles of Hg, lead (Pb), manganese (Mn) and iron (Fe) in fifteen dated Arctic sediment cores over a 3-year period, with the main focus on Hg.
2. To quantify geographical trends in fluxes of Hg and its enrichment factors in Nunavut, the Northwest Territories (NWT) and Nunavik.
3. To link Hg findings with those of paleolimnological indicators, persistent organic pollutants (POPs), as well as indicators of biogeochemical processes of Mn and Fe, all of which are obtained from the same cores or cores from the same sites, whenever possible.
4. To complement existing data on Hg in Arctic sediment cores with data generated over a much wider latitudinal and longitudinal range than previous work, in order to provide a better understanding of Hg in Canada's North.
5. To provide loading data for Pb, which may help elucidate the understanding of Hg pathways and sources.

Introduction

Mercury has emerged as a priority contaminant in the Arctic and in inland lakes of central and eastern Canada, given evidence for increasing levels of Hg in biota (Braune 1999, Muir et al. 1997, Pierce et al. 1998) and in lake sediments (Barrie et al. 1997, Landers et al. 1998). Several recent Northern Contaminants Program (NCP) studies have dealt with Hg pollution, for example: *Mercury and their contaminants in a laminated sediment core* (Lockhart et al. 2000a); *Atmospheric transport, oxidation and fallout in Nunavik* (Poissant 2000); *Mercury measurements in Alert* (Schroeder 2000); *Mercury in Salluit* (Dewailly 2000); and *Mercury in fish* (Lockhart et al. 2000b). This project attempts to address the major gap identified by Landers et al. (1998) – the need for a wide spatial scale of Hg deposition as inferred from sediment cores – and proposes to study 15 sediment cores over a 3-year period; five sediment cores are reported here. The project, which began in April 2000, complements the NCP study at Devon Island (Lockhart et al. 2000a) by investigating the fluxes time series for Hg in sediment cores collected from various parts of the High Arctic, central NWT and northern Quebec. In addition to Hg, Pb, Mn and Fe are included. Results that assess the diagenesis (redox cycling) of Hg, if any, by using similar approaches used by Gobeil et al. (1999) are also reported.

Activities in 2000-2001

The five sediment cores studied were taken from Lake AXAJ, Lake Baird Inlet, Lake Oksana, Rummy Lake and Lake TK-54. Figure 1 shows their approximate locations and indicates those that have been and will be cored. These cores were collected for a Toxic Substances Research Initiative study on POPs and paleolimnologicals (Muir 2000), and the sediment slices were shared for this study. Sediment cores were obtained with a 10 cm diameter KB corer or a Glew corer (Glew 1988) through holes drilled into the ice, from a small boat or from a float-equipped Cessna 206 or other aircraft. Cores were extruded on site and slices placed in polyethylene (WhirlPak®) bags. Slice thickness depended on apparent sedimentation rates. In low sedimentation systems, typical of High Arctic lakes, slice thickness was 0.5 cm for the top 5 cm (i.e. to achieve maximum temporal resolution while obtaining sufficient mass for ^{210}Pb dating and contaminant analysis). At more southerly locations, with typically higher sedimentation rates, slice thickness was 1 cm. Table 1 lists the lake sediment cores studied this year with their positions, dated radioisotopes and sedimentation rates. Lakes Baird Inlet and AXAJ were ^{210}Pb-dated at the National Water Research Institute (NWRI), Burlington, whereas the other three lakes were dated with ^{210}Pb and ^{137}Cs at the Freshwater Institute, Winnipeg.

Figure 1. Approximate locations of cores that have been analyzed and collected, and those planned for collection

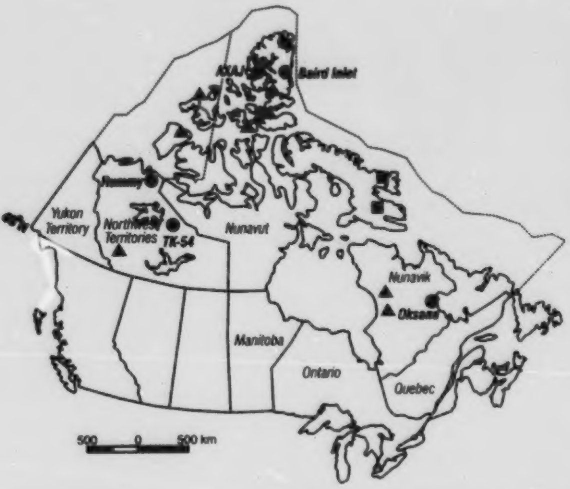


Table 1. List of lake sediment cores studied and its sedimentation rates

Sediment cores	Latitude	Longitude	Dated Radioisotopes	Sedimentation rate $g\cdot cm^{-2}\cdot y^{-1}$
Baird Inlet Lake	79°20'N	75°00'W	^{210}Pb	0.001
Lake AXAJ	80°00'N	87°00'W	^{210}Pb	0.01
Lake Oksana	54°48'N	66°47'W	^{210}Pb, ^{137}Cs	0.005
Rummy Lake	63°00'N	122°30'W	^{210}Pb, ^{137}Cs	0.008
TK-54 Lake	64°31'N	112°42'W	^{210}Pb, ^{137}Cs	0.0065

Approximately 0.25 g of homogeneous freeze-dried sediment was weighed into a Teflon vessel and 10 mL of nitric acid, 2 mL of hydrochloric acid and 1 mL of hydrogen peroxide were added. The vessel was assembled, sealed and fitted onto a microwave rotor, which was placed in a high-pressure microwave oven (MLS 1200 Mega, Milestone). The sample was digested in the microwave field and the temperature maintained at 200°C for 15 minutes. The vessel was removed from the microwave oven and the cooled digest was brought to 100 mL volume with deionized water. The high temperature and the strong oxidizing conditions of the digestion ensured destruction of the substrate and good recovery of analytes. The resultant solution was analyzed for Pb by inductively coupled plasma-mass spectrometry (ICP-MS) (PQ-2, VG Elemental); Hg by cold vapour atomic absorption spectrometry (CV-AAS); and Fe and Mn by ICP atomic emission spectroscopy (ICP-AES). Mercury (II) was reduced to elemental Hg in an automated continuous flow system by the action of stannous chloride. The Hg was sparged from the solution with a stream of purified air and passed through an absorption cell of a Hg analyzer (LDC/Milton-Roy). For reactive Fe and Mn, a 1N HCl extraction was used (Leventhal and Taylor 1990, Gobeil et al. 1999). Both reactive and total extractable Fe and Mn were analyzed using ICP-AES. The National Laboratory for Environmental Testing (NLET), NWRI, Burlington, analyzed all samples. NLET is a certified analytical laboratory, which participates regularly and performs consistently very well in the NCP interlaboratory studies as well as in the regional, national and international intercomparison exercises.

Results and Discussion

Prior to the actual analysis, methods validation was carried out to ensure precise and accurate long-term data generation of Hg, Pb, Fe and Mn. Certified sediment reference materials were used to ensure precise and accurate recoveries of metals. Different weights of real sediments were tested to arrive at a small, optimum weight to be used so that thin slices of sediment (small weight) could be effectively analyzed to give reliable results. Furthermore, we tested the long-term ruggedness of methods by having two different analysts analyze 40 different sediment samples 6 months apart. All the validation results were satisfactory and have been presented elsewhere (Cheam et al. 2000, 2001a, 2001b).

The excess ^{210}Pb data for the five sediment cores, shown in Figure 2, indicates a general rapid decline of the isotope from the 1990s to the 1900s; this indicates overall that the slices are date-distinguishable and thus can be used to study spatial loadings of pollutants. Some of the cores are also supported by the ^{137}Cs data (Figure 2). For Lake TK-54, the ^{137}Cs data show a spike in 1987, which corresponds well to the Chernobyl reactor accident in 1986. Also, it shows a large spike in 1958; this corresponds closely to the testing of nuclear bombs which released ^{137}Cs into the atmosphere in the early 1960s. Lake Rummy has a spike of ^{137}Cs around 1988, approximately coinciding with the Chernobyl accident in 1986, but does not have an apparent peak around 1960s. However, since the deposition dates are estimated based on mid-points of slices, the "possibly-abundant" ^{137}Cs activities around 1960 (in the middle of 1973-1948 time span, which corresponds to the point furthest away from the 1973 and 1948 mid-points) could well have been missed in the measurement process. Lake Oksana has a broad peak of ^{137}Cs activities covering the 1987-1971 time span, but curiously has no peak around the 1960s.

Figure 3 shows the depth profiles for Hg, Fe, Mn and Pb in the five sediment cores. For Hg, the recent slices (~ 1970-2000) contain higher fluxes than the pre-industrial slices (~ 1860 or older). Although it is not readily obvious for Lake Oksana and Lake TK-54, the calculation of fluxes indicates excess in the recent slices.

For Hg, Fe and Mn, there is no indication of movement of Hg with Fe and Mn as their profiles are not synchronous, i.e. they do not have the same general pattern as observed by Gobeil and Cossa (1993) for marine sediments from the Laurentian trough. Even in their situation, the authors showed that the redistribution of Hg represented only a minor fraction of the total Hg deposited at the surface.

Thus, it seems there is no redistribution of Hg in our sediment cores and the observed Hg profiles represent the true deposits at the surface.

While most studies using lake sediments have shown that Hg profiles reflect atmospheric trends and fluxes (e.g. Fitzgerald et al. 1998, Lockhart et al. 1998, Landers et al. 1998), there is a potential for post-depositional movement during diagenesis producing distortions in vertical profiles (Rasmussen 1994, Gobeil et al. 1999). To evaluate this possibility, this study included determination of Fe and Mn using a 1N hydrochloric acid extraction (Gobeil et al. 1999) to liberate the reactive phases such as Mn and Fe oxyhydroxides. While Gobeil et al. (1999) observed some correlation between the percent reactive Fe and total Hg concentration in marine sediment cores from the Arctic basins, indicating some degree of Hg movement with Fe, our data to date indicates no apparent correlation between the two concentrations. Figure 4 plots the percent reactive Fe versus total Hg concentrations for four cores (the fifth core from Lake Baird Inlet did not have enough mass for this experiment) and shows a lack of any correlation. Also, it must be noted that in Gobeil et al. (1999) sediments were quite different from this study's as they were marine in nature, collected from a

Figure 2. ^{210}Pb and ^{137}Cs activities in core slices from Lakes Rummy, TK-54, Oksana, Baird Inlet and AXAJ

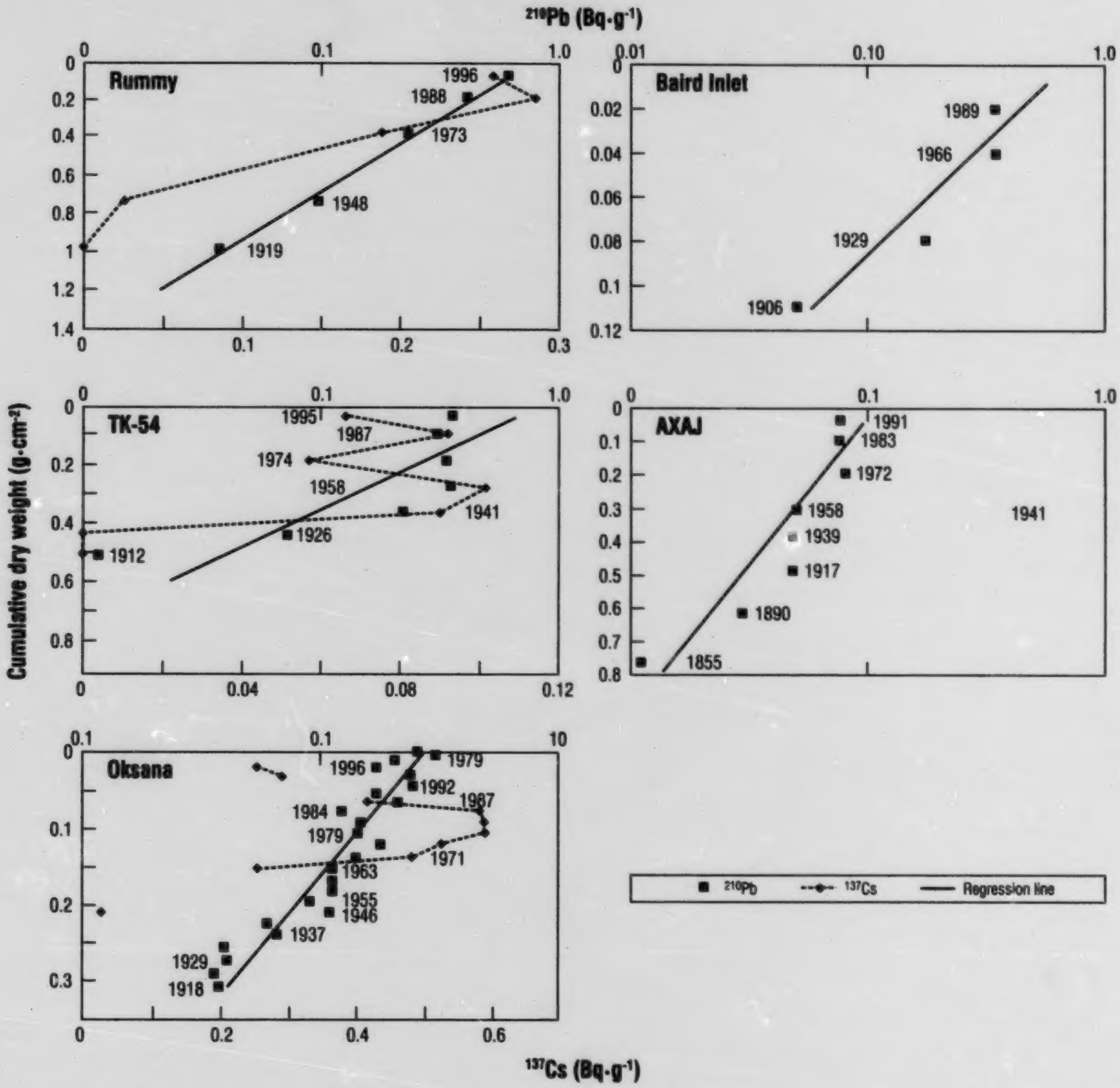


Figure 3. Fluxes of Hg, Fe, Mn and Pb ($\mu g \cdot m^{-2} \cdot yr^{-1}$)

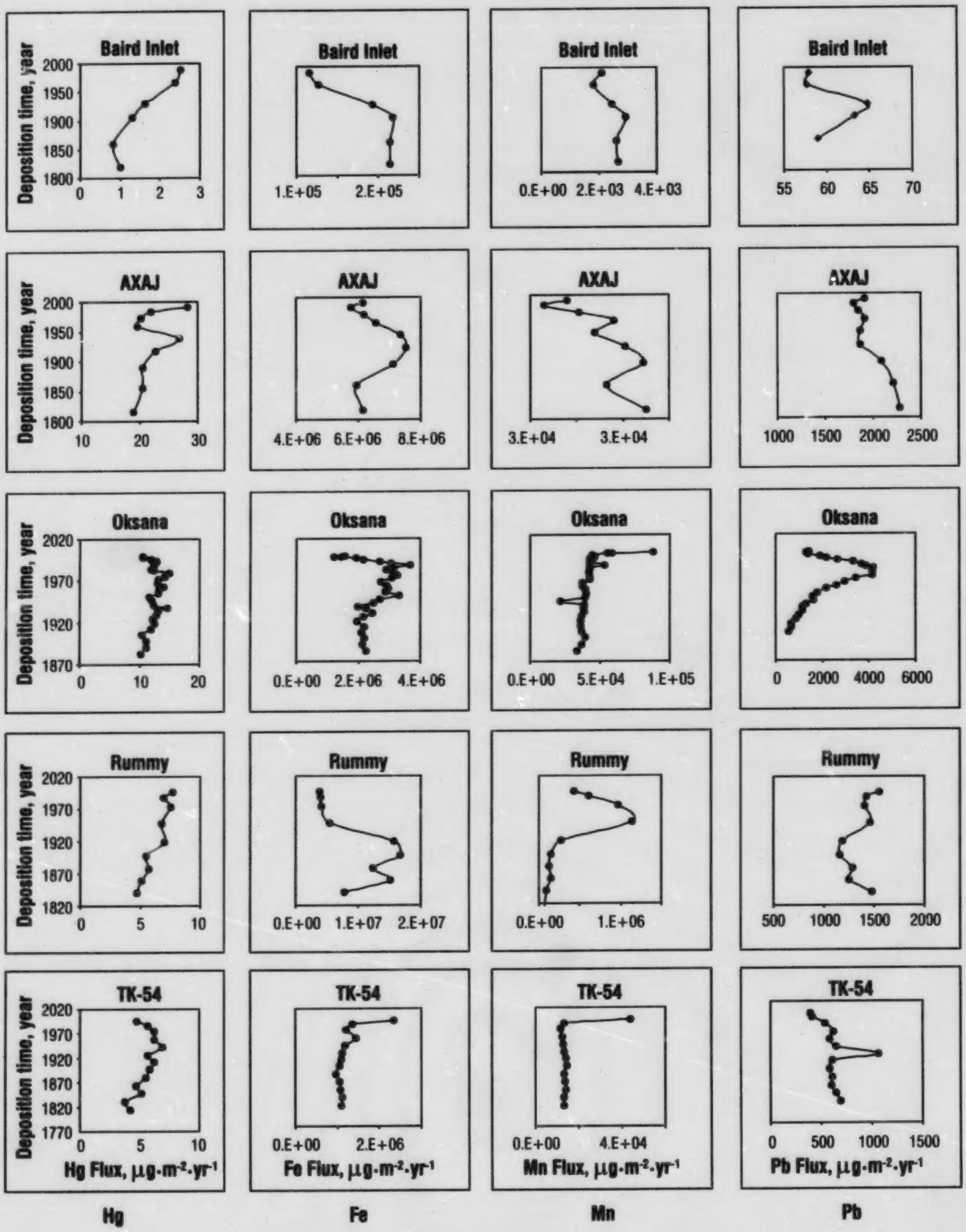


Figure 4. Apparent independence of total Hg and reactive iron in 4 different cores from Lakes Oksana, AXAJ, Rummy and TK-54

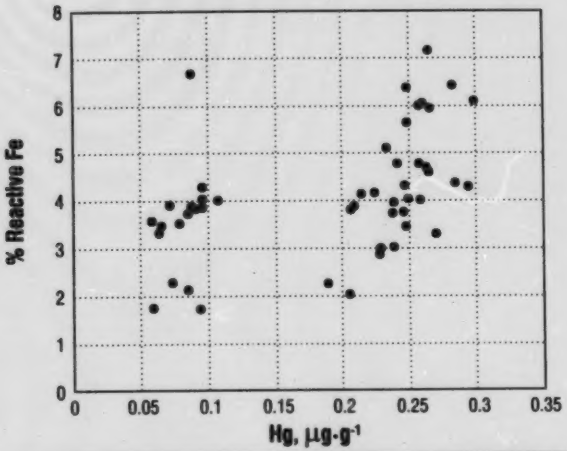
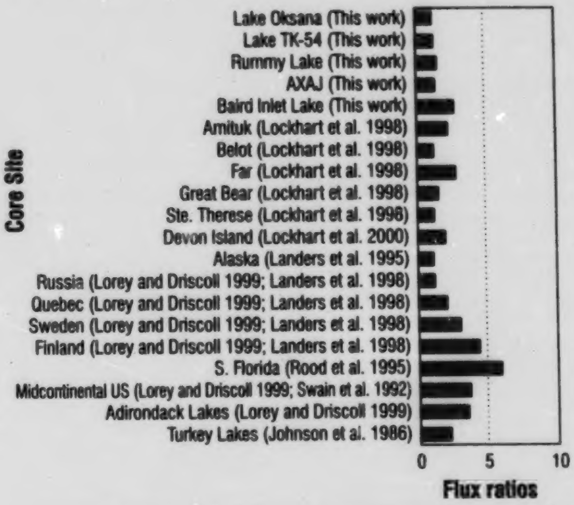


Figure 5. Comparison of flux ratios



very deep depth (~ 2500 m to 4500 m) and the sedimentation rates were extremely low (< 1 cm·ka^{-1}). Our data is in agreement with those of Lockhart et al. (2000c), who showed negligible diffusion and remobilization of Hg after deposition for three different sediment cores from Clay, Giauque and Stuart Lakes, where profiles corroborate very well with the well-recorded historical Hg emissions nearby those lakes.

The Pb profile for Lake Oksana is a revealing one; it peaks in the period of 1970 to 1980, when the maximum of alkyl Pb in gasoline was used, up to the early 1970s, followed by the gradual phase-in of unleaded gasoline, until 1980. The other four cores did not have Pb peaks, as in the Lake Oksana core. It is somewhat surprising that no Pb peaks were observed in these four cores, especially when Cheam et al. (1998) observed Pb pollution peaks in a snow pit during the period from 1986 to 1993 at Agassiz Ice Cap, Nunavut, or when other researchers observed the rise and fall of Pb concentrations in ice cores from Greenland (Candelone et al. 1995). Analyses of several sediment samples were also made for Pb isotopes 206, 207, 208 and 204, although no definite pattern was apparent and no specific information could be derived from the data at this time. Additional attempts will be made and will hopefully provide some useful information as to the metal origins.

The metal flux in sediments (μg·cm^{-2}·yr^{-1}) was calculated as the product of sedimentation rate (g·cm^{-2}·yr^{-1}) and concentration (μg·g^{-1}) in the samples. The fluxes were obtained for the five lakes for Hg, Pb, Fe and Mn. By assessing the relationship between metal fluxes in the pre-industrial era and fluxes in the recent era, an enrichment factor or flux ratio could be calculated.

Enrichment factors for Hg in the range of 1.20 to 2.69 were calculated, which are about the same order of magnitude as those reported for some other parts of the Arctic, including Lake DV09 on Devon Lake (Lockhart et al. 2000a) and Alaska (Landers et al. 1998), but lower than those reported for south Florida (Rood et al. 1995), mid-continental US (Swain et al. 1992), Adirondack lakes (Lorey and Driscoll 1999), Lake Tahoe (Heyvaert et al. 2000) or lakes by the inland ice cap in Kangerlussuaq, Greenland (Bindler et al. 2001). Figure 5 compares the enrichment factor for the studied lakes to those in other parts of Canada, the United States and Europe.

Conclusions

The results of the first year of this research add significant findings to the existing data available for North America and Europe. Recent fluxes in Hg are higher than pre-industrial ones, and the resulting enrichment factors range from 1.2 to 2.7, which are in general accordance with the published data for other northern regions. So far, the data on Hg, Fe and Mn (total and reactive) altogether strongly suggest that there is no remobilization/redistribution of Hg with the Fe and Mn during the diagenesis. We are looking forward to further research in 2001-2002 with anticipation as five more cores will be studied. It is hoped that more significant findings will be reported, which further confirms the no co-movement of Hg with Fe and Mn. Additionally, new data on Hg and Pb isotopes could be useful in determining the metal origins. Finally, as more data accumulate, we hope to generate the general pattern of Hg deposition in Canada's North and to assess the concept of cold condensation raised by Wania and Mackay (1993).

Expected Project Completion Date

March 31, 2003

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The Seasonal Cycle of Organochlorine Concentrations in the Canada Basin

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Abstract

The Surface Heat Budget of the Arctic (SHEBA) project has provided a unique opportunity to collect organochlorine data during a complete year in the western Arctic Ocean. Analyses have been completed for air, water and ice, particles, algae, zooplankton (sorted size fractions), invertebrates and fish. Preliminary examination of the data reveals that ocean processes are important contributors to contaminant distributions. In particular, the interior ocean carries a polychlorinated biphenyl (PCB) signature that contains enriched lighter PCBs characteristic of distillation whereas the Chukchi Shelf water appears similar to Arochlor formulations with prominent contribution from the pentaCBs. Pesticides appear to be redistributed in the water column through biological productivity, which removes dieldrin, DDT and chlordane from surface water but releases them again in water below about 100 m during biological regeneration.

Key Project Messages

1. Water entering from the Bering Sea, measured in April 1998, contains an Arochlor 1254 or Sovol-like signature in contrast to the interior water of the Canada Basin which clearly carries a PCB signature containing a "distillation" component favoring the lighter chlorinated biphenyls (CBs).
2. In contrast to hexachlorocyclohexane (HCH), where concentrations are found to decrease from their highest values near the surface to very low values below 200 to 300 m, preliminary data for DDT, dieldrin and chlordane show trends suggestive of vertical transport and enrichment at depths where biological particles regenerate.

Objective

- Measure the intra-annual variability of contaminant transport and food-web accumulation in the Canada Basin from October 1997 to October 1998 from the drifting platform provided by the Canadian Coast Guard Ship (CCGS) *des Groselliers* and the Surface Heat Budget of the Arctic (SHEBA) project.

Introduction

The SHEBA project was planned around the intentional besetting of a research vessel (CCGS *des Groselliers*) in the permanent pack of the Beaufort Gyre for a complete year beginning in early October 1997 (Welch 1998, Perovich et al. 1999). Given the platform and the physical studies to be conducted, SHEBA provided an invaluable opportunity to conduct research on the physical and biological processes that deliver, redistribute and biomagnify organochlorine (OC) contaminants in this region.

The Beaufort Gyre can be thought of as a large, relatively isolated ice-covered "mesocosm" in the interior Canada Basin. Previous work has shown this region to contain high concentrations of HCH (e.g. Hargrave et al. 1988, Macdonald et al. 2000a, Macdonald et al. 2000b) and it was suspected that other pesticides with low Henry's Law constant might similarly be enriched. Several factors are thought to contribute to this region's sensitivity to persistent organic pollutants (POPs), including cold water, ice cover, low particle fluxes in the water and long residence time of the surface water (Macdonald et al. 2000a). Recent studies have shown the Canada Basin to contain a large reservoir of surface water which cannot easily shed its contaminants and which will therefore affect downstream locations (especially the Canadian Archipelago) for years to come (Macdonald et al. 1997, Macdonald et al. 1999b).

During the SHEBA drift (Figure 1), samples were collected at intervals to measure POPs concentrations in air, water and ice, particles, algae, zooplankton (sorted size fractions), invertebrates and fish with the intention of observing how the ocean maintains contaminant burdens in the euphotic zone and how such contaminants transfer into the food web. The samples retrieved during SHEBA will provide information about the relationship between seasonal ice formation and melt, seasonal atmospheric transport and water column OC concentrations in the Canada Basin, and the coupling of water-borne contaminants into and up the food chain. Because personnel remained on the platform throughout the year's drift, there was an opportunity to collect large-volume samples using Infiltrex pumps and filters to yield valid data for OCs of concern like PCBs, chlordane and toxaphene. A full biological program allowed the collection of many different species which could be sorted on site into trophic levels. Analysis of stable isotope composition ($\delta^{13}C$, $\delta^{15}N$) and OC concentration will allow a detailed look at the distribution of OCs as a function of trophic level and/or predator-prey relationships. Finally, physical and chemical data collected during the drift will allow the interpretation of OC data in the context of oceanographic processes which include seasonal stratification/ destratification and changes in water masses experienced during the drift. Data such as these are impossible to collect from ships carrying out transects simply due to time constraints and are, therefore, noticeably absent from recent assessments (e.g. Barrie et al. 1998, Macdonald et al. 2000a).

Activities in 2000-2001

Effort has been spent on:

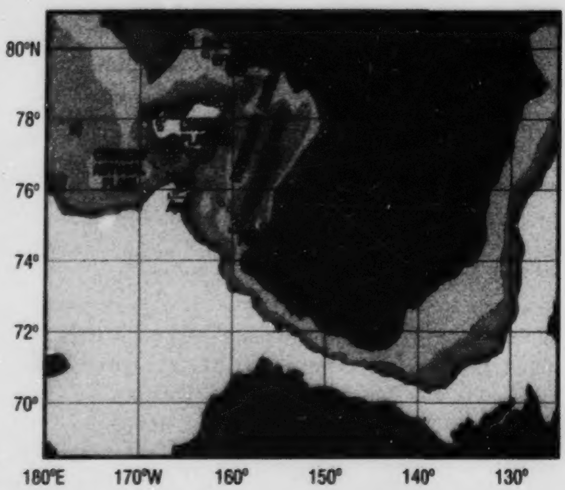
- Completing the analyses of samples collected during SHEBA.
- Collating the OC and isotope data into spread sheets.
- Interpreting ancillary physical and geochemical data to understand the oceanographic context of the SHEBA drift.
- Conducting a preliminary examination of the OC data.

At this time, all data are in hand, but the large task of interpreting and publishing the data in journals remains.

Results and Discussion

During the planning stages, we anticipated that the seasonal ice cover would provide a dominant influence on surface-water concentrations of OCs, and that we would witness the entry of contaminants from the ice surface in spring when the ice melted, discharging its inventory to the surface ocean. In view of the large size of the reservoir of the interior ocean and its slow decline in HCH burden as measured since the late 1980s, we did not expect there to be an obvious spatial signal, nor did we expect to see a significant downturn in contaminant inventories over the 1-year period of the drift. Accordingly, SHEBA was viewed as a large mesocosm representative of the interior surface pool of the Beaufort Gyre, providing an opportunity to produce detailed, accurate vertical profiles for most of the OC contaminants in the top 250 m

Figure 1. The SHEBA drift*



* The SHEBA drift is indicated by the open squares which identify where conductivity-temperature-depth (CTD) profiles were collected. OC profiles in the water column were collected during the six time intervals indicated along the drift as marked (November 1997, December 1997, February 1998, April 1998, July 1998 and September 1998)

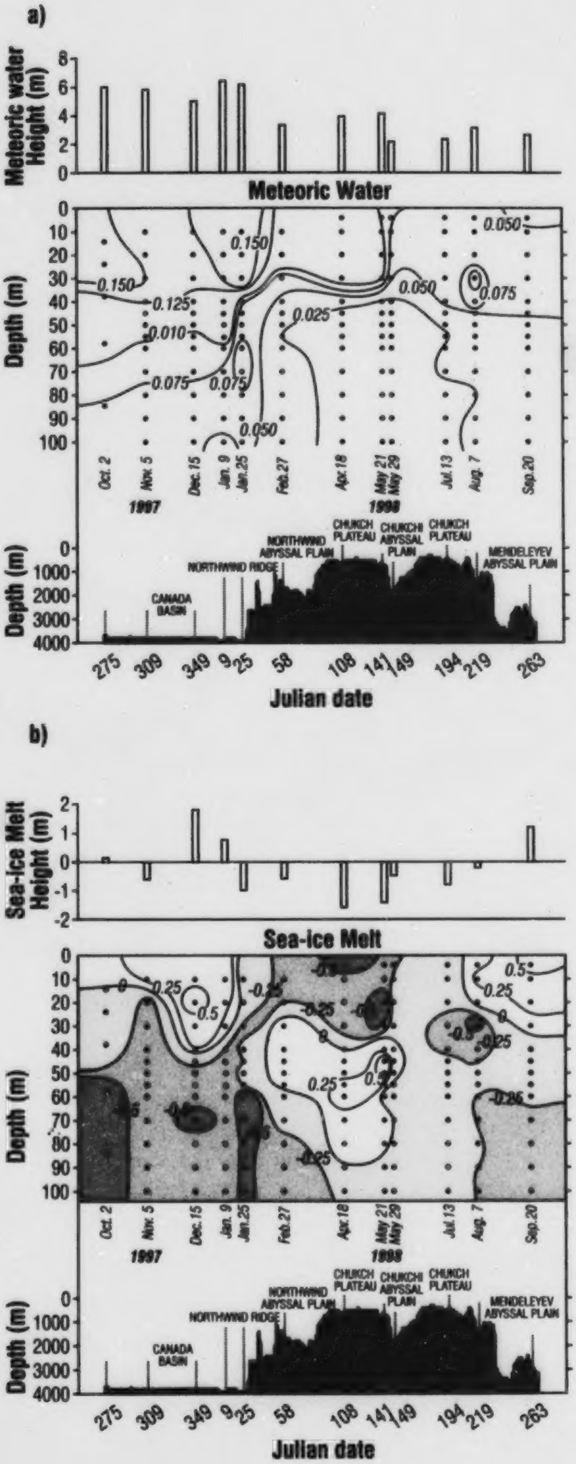
and to determine the pathways of these OCs into biota (both pelagic and ice algae).

SHEBA drifted westward, rapidly at times, exiting the Canada Basin before February to drift over the Chukchi Cap for 6 months before re-entering deep water in the Mendeleyev Abyssal Plain late in the program (Figure 1). As a consequence, the SHEBA time-series was primarily a transect which passed through watermass changes that clearly must be taken into account when interpreting trends in the OC data. The first complete set of transect data for OCs (bottle samples for α- and γ-HCH [Macdonald et al. 1999c]), showed relatively high concentrations of HCH under the pack ice in the interior Beaufort Sea. When SHEBA passed over the Chukchi Cap, the concentrations dropped dramatically reflecting the concentrations of HCH isomers in Pacific Ocean water that had recently entered the Arctic Ocean through the Bering Strait. This section, therefore, provided the first coherent transect connecting two regions where HCH time series have been maintained, one in the Canada Basin (Hargrave et al. 1988, Macdonald et al. 1999c) and one in the Bering and Chukchi Seas (Jantunen and Bidleman 1995, Jantunen and Bidleman 1998). The spatial distribution of HCH suggests that the marginal seas are clearing more rapidly than the interior ocean due partly to enhanced air-sea exchange over the shelves, which have less severe ice cover, and partly to more rapid replacement of shelf water by inflowing Pacific Ocean water.

During the 1990s, the Arctic Ocean underwent dramatic change in watermass distribution and ice drift trajectories (Carmack et al. 1995, Macdonald 1996, McLaughlin et al. 1996, Carmack et al. 1997, Proshutinsky and Johnson 1997, Dickson 1999, Macdonald et al. 1999a). This change became all too evident during the launch of SHEBA when thick, multi-year ice could not be found and the ocean's surface was observed to be exceptionally fresh (Welch 1998, Perovich et al. 1999).These two observations – thin ice, fresh surface water – have caused many to infer enhanced ice melt in Canada Basin during the 1990s. However, our SHEBA stable isotopic data ($\delta^{18}O$) which allow us to discriminate between ice melt and runoff show that most of the freshening was caused by enhanced amounts of runoff (Figures 2a, 2b). The source of fresh water is important not only for understanding the recent changes in the oceanography but also for understanding the potential sources for contaminants. Recent work has uncovered a large shift in Arctic Ocean water properties and ice drift trajectories forced primarily by atmospheric pressure fields (McLaughlin et al. 1996, Proshutinsky and Johnson 1997, Macdonald et al. 1999a). Perhaps even more relevant to contaminant transport pathways, it has been discovered that runoff entering the Laptev and Kara Seas no longer feeds the transpolar drift but during the 1990s appears to have been diverted to the east to enter the Canada Basin (Ekwurzel et al. 2001, Guay et al. 2001).

What these watermass changes will mean for contaminants is not yet clear, but some startling images are emerging from the SHEBA data. In Figures 3a to 3d, the PCB data collected from Infiltrex pumps deployed over the top 250 m of the water column show a remarkable transition from the Canada Basin to the Chukchi Cap (compare Figure 3a with 3b). The February profile, on the eastern flank of the Northwind Ridge (Figure 1) suggests a two-component PCB mixture: there are enhanced lighter PCBs (mono, di and tri congeners) but there is also an underlying envelope similar to PCB technical mixtures or the Russian technical mixture called Sovol (Schulz et al. 1989, Ivanov and Sandell 1992; Figure 3e). Over the southern edge of the Chukchi Cap (April; Figure 1), the profile looks far more strongly influenced by the technical mixture component (Figure 3b). As SHEBA drifted back toward the interior ocean, the profiles in July (Figure 3c) and September (Figure 3d) revealed a strengthened light PCB component. Although variations are evident within the vertical profiles, the predominant feature of these data is one of a two-component mixture distributed unevenly in space. Given the stratification of the water column and the ice cover, it is difficult to imagine the

Figure 2. The fractional composition of (a) fresh water from runoff along the SHEBA drift and (b) ice melt along the SHEBA drift

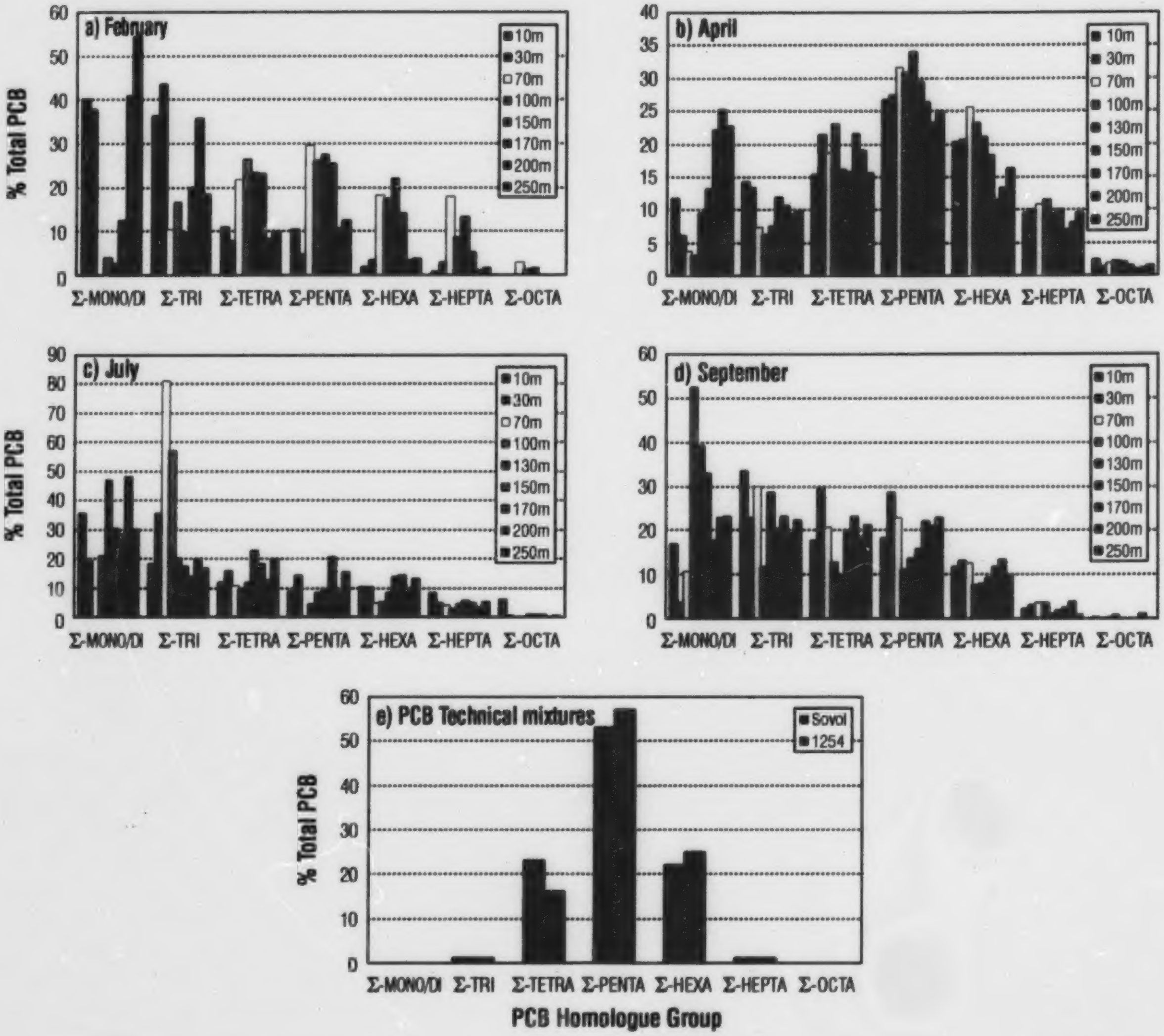


changes shown in Figure 3 being caused by in situ processes (e.g. air-sea exchange, ice melt, runoff, biological activity). It seems much more plausible that the PCB compositions along the track reflect the various water masses through which SHEBA passed. The oceanographic properties along the SHEBA drift track clearly show structure associated with the bathymetry of the Chukchi Plateau and that SHEBA passed through boundaries along its drift through this complex bathymetric region (Figure 2a). The dominant contribution of technical mixture, seen in April (Figure 3b), suggests strongly that this profile has been imported from the Pacific Ocean. The profiles collected in February, July and September, on the other hand, probably reflect a stronger influence of Canada Basin interior water which has accumulated an important component of its PCB inventory through the atmosphere. The inference to be drawn here is that PCBs have been delivered via the Pacific Ocean in water directly contaminated through, for example, runoff or spills, whereas the interior Arctic Ocean owes a significant portion of its PCB content to condensation and/or air-sea exchange which favours the lighter components as one progresses northward (Wania and Mackay 1993, Muir et al. 1996). Total PCB water concentrations, averaged over the entire vertical collection range, for April, July and September were 115.3, 31.3 and 45.4 pg×L^{-1}, respectively.

Preliminary data for DDT, dieldrin and chlordane (Figures 4a to 4c) reveal vertical distributions very different from those observed for the HCHs where concentrations are found to decrease from their highest values near the surface to very low values below 200 to 300 m. From the oceanographic and PCB data shown in Figures 2 and 3, we can anticipate that changes in the pesticide profiles might in part be caused by watermass change. However, taking DDT as perhaps the best example, it seems likely that there is also a seasonal signal related to the biological cycle. In April and February of 1998, the DDT profiles were somewhat noisy, but reasonably uniform at about 2 pg·L^{-1} through the water column down to 250 m (Figure 4a). By July, however, this uniformity has been destroyed with much lower DDT concentrations evident in the top 100 m to 150 m and higher concentrations at about 200 m to 250 m. In September, the surface concentrations of DDT are again centred at about 2 pg·L^{-1} but higher concentrations are evident at or below about 150 m. Although watermass changes may contribute partly to the observed behaviour, there appears also to be a transfer of DDT from surface to deeper water in spring when biological production produces a vertical flux of organically rich particles.

Dieldrin (Figure 4b) and chlordane (Figure 4c) do not show a clear seasonal pattern, but they show trends

Figure 3. The PCB congener distributions for the vertical profiles collected in (a) February, (b) April, (c) July and (d) September. Also shown (e) is a representative PCB distribution for the technical mixture Arochlor 1254 and the Russian formulation Sov20.



suggestive of vertical transport and enrichment at depths where biological particles regenerate.

Conclusions

SHEBA has produced a large, complex and unique data set for oceanographic properties and OC contaminants in water, air and biota. The small part of the data discussed here and elsewhere (Macdonald et al. 1999c) show a remarkable potential to apply these data to understand the transport processes for the various OC contaminants and their cycling in the upper ocean. Not shown here is an accompanying data set for OCs in biota. Together, the two data sets will shed light on how contaminants have entered the western Arctic Ocean, how they are distributed in the water column and how they enter the food web.

Expected Project Completion Date

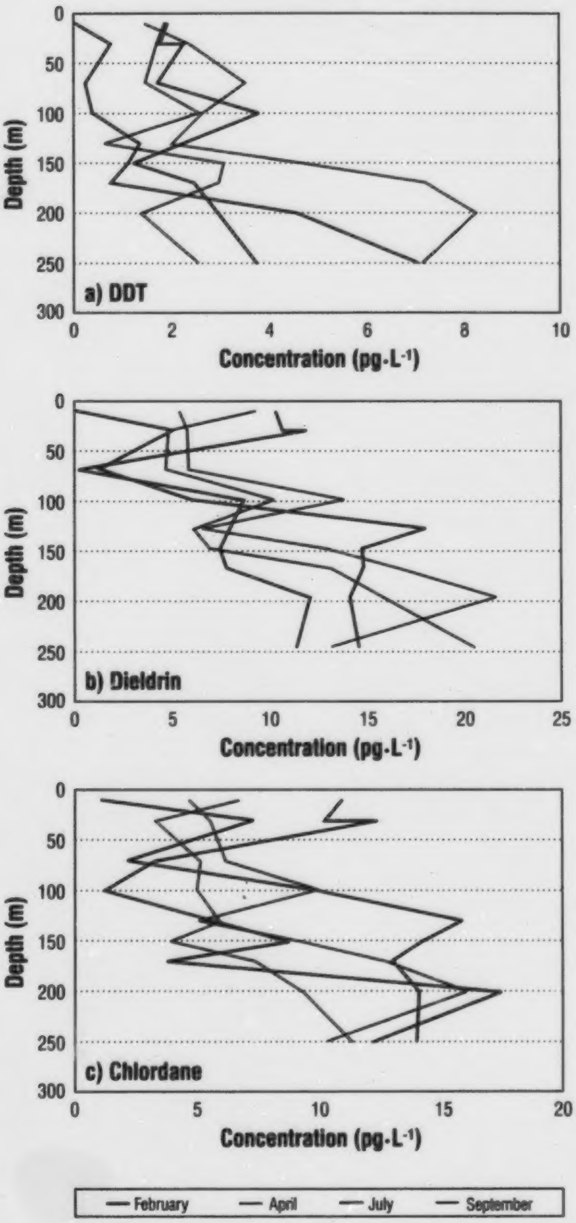
March 31, 2002

Acknowledgments

We thank the officers and crew of the *des Groselliers* and the Canadian Coast Guard for remarkable commitment to

conduct the deliberate besetting of a ship in the Canada Basin, and the Northern Contaminants Program for providing funds to collect and analyze the samples.

Figure 4. Vertical profiles during four sampling intervals (February, April, July and September, 1998) for (a) DDT, (b) dieldrin and (c) chlordane



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Atmospheric Mercury Transport, Oxidation and Fallout in Northern Quebec (Nunavik): an Important Potential Route of Contamination

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Abstract

Recent observations of mercury and ozone concentrations along Hudson Bay in Kuujjuarapik, Quebec, (latitude 55° N) showed that mercury and ozone depletion events, originally observed in the high Arctic region, appeared at latitudes as low as 55° N. Depletion events were concomitant with large bromine monoxide concentration clouds, such as observed by the Global Ozone Monitoring Experiment satellite over Hudson Bay. Gaseous mercury speciation, air-snow mercury gas exchange flux measurements, as well as mercury concentrations surveyed in snow during a depletion event suggested that most of the mercury fallout occurring during depletion events is in the particle phase, is labile and very reactive (photoreducible). Indeed, following a depletion event, mercury concentration in the snow pack increased by up to 1600% of its pre-depletion event concentration, but about 50% of this newly deposited mercury in snow was lost within 12 hours following deposition. It is suggested that freshly deposited mercury is quickly emitted back to the atmosphere through air-snow gas exchange fluxes.

Key Project Messages

1. Mercury (Hg) depletions have been observed in the low Arctic.
2. Hg fallout occurs during these depletion events.
3. Hg escapes back partly to the atmosphere after depletions.

Objectives

1. Measure gaseous elemental mercury (GEM) concentrations in air at Kuujjuarapik (Hudson Bay, 77° 75' W 55° 28' N) and to study their relationship with other locations in Canada, e.g. Canadian Atmospheric Mercury Network (CAMNet).

2. Study Hg oxidation processes by measuring ozone in the air.
3. Measure total Hg concentrations in precipitation (as well as major ions, such as Cl^- and Br^-) in precipitation at Kuujjuarapik and to study their relationships with long-range transport and Hg fallout.
4. Measure Hg surface-air fluxes, especially during springtime.
5. Measure Hg concentrations in various abiotic components (soil, water, snow, etc.), over space and time in Nunavik and to study their potential connection with atmospheric Hg fallout.

Introduction

Mercury is one of the most toxic chemicals in the environment. It is of particular concern in northern areas as it can reach these regions through long-range transport (Poissant 1999, Poissant 2000, Cheng and Schroeder, 2000) and be chemically transformed (Schroeder et al. 1998). Moreover, Hg bioaccumulates in the Arctic food chain (Macdonald et al. 2000).

Atmospheric ozone and Hg depletion events were recently discovered in the high Arctic region during polar sunrise experiments (Barrie et al. 1988, Schroeder et al. 1998). It is accepted that catalytic cycles involving bromine monoxide (BrO) are responsible for the majority of observed ozone losses; smaller contributions being proposed for cycles involving chlorine monoxide (ClO) and iodine monoxide (IO) (Barrie et al. 1988, Richter et al. 1998). Reactive bromine species contribute significantly to the destruction of ozone in the polar stratosphere as well as the underlying troposphere (Barrie et al. 1988, Bottenheim et al. 1986) and can be an effective oxidant for Hg (Schroeder et al. 1990, Schroeder et al. 2000). However, the complete Arctic Hg oxidation mechanisms are still enigmatic (Schroeder et al. 2000). Chemical conversion of Hg° would yield either particle-phase or reactive gaseous Hg species associated with dry deposition (Schroeder et al. 1998).

Bromine monoxide columns are observed over the Hudson Bay area and parts of the Canadian Arctic (Richter et al. 1998). Satellite observations, from the Global Ozone Monitoring Experiment (GOME), showed that tropospheric air masses enriched in BrO are always located close to sea-ice and typically extend over areas of about 300 to 2000 km. The BrO abundance remains enhanced for periods of 1 to 3 days, especially in late winter and springtime (Richter et al. 1998, Wagner and Platt 1998). The sources of bromine in polar spring are not well understood but would involve a marine source (Richter et al. 1998).

This study presents measurement data that offer a unique opportunity to study the temporal evolution of ozone and Hg depletion events in the low Arctic, and contributes significantly to the discussion on atmospheric Hg transport and its fate in northern environments. This issue is critical for assessing the mechanistic route of Hg contamination into the North and its further transfer to the biosphere.

Activities in 2000-2001

Various activities were done in the second year of this Northern Contaminants Program (NCP) research project. The study site is located in Kuujjuarapik, Nunavik, at the Centre d'études nordiques (CEN), University of Laval. Meteorological data are available from the CEN and Navigation Canada. Gaseous elemental mercury, previously referred to as total gaseous mercury (TGM), and ozone instruments were installed in mid-August 1999 and Hg and ozone data (GEM at 15-minute intervals; O_3 at 5-minute intervals) were collected daily through telemetry (Poissant et al. 1996). Gaseous elemental mercury measurements were audited (quality controlled) at the site during a national audit conducted by CAMNet in mid-November 2000. Internal audits are conducted every 4 months following the same protocol (Poissant and Casimir 1998). GEM data are quality controlled through the Research Data Management and Quality Assurance System™ Hg package (National Atmospheric Chemistry Database), Measurements and Analysis Research Division, Meteorological Service of Canada, Downsview).

A cost effective and high quality monthly sampling protocol for Hg and major ions was developed and applied. Precipitation samples have been collected since September, 1999, and analyzed for Hg, bromide and chloride at INRS-Eau by M. Amyot. In spring 2000 and 2001, two intensive field campaigns were completed. Mercury snow surveys were done in the Kuujjuarapik area; sample analysis is ongoing. Also, snow-air Hg gas exchange flux experiments were conducted. These were the first Hg flux measurements conducted in the Arctic. Measurements of reactive gaseous mercury, GEM, ozone, GEM flux and Hg in snow were done simultaneously.

Daily satellite data for BrO concentration in the Arctic domain were collected by GOME (GOME 2000).

In the spring of 2001, a European research team did parallel chemistry measurements using differential optical absorption spectroscopy. In situ measurement of BrO has revealed a mixing ratio of up to 30 ppt (G. Hoenninger, personal communication).

Results and Discussion

GEM and ozone results

Table 1 presents a statistical summary of daily GEM and ozone measurements at Kuujjuarapik from August 1999 to April 2001. The daily median value was 1.75 ng·m^{-3}; minimal values of GEM and ozone were found to be low, 0.29 ng·m^{-3} and 1.28 ppbv, respectively.

Figure 1 shows the daily median time series of GEM and ozone at Kuujjuarapik. This historical time series shows specific low Hg and ozone concentrations from February to April. Two springtime periods have been measured to date and both showed distinct climatology. Indeed, springtime 2000 showed larger and deeper depletion events than springtime 2001. The largest depletion event was recorded on March 15, 2000. This event impacted the atmospheric chemistry at Alert, Nunavut, which is located at 82.50° N (J. Bottenheim, personal communication). The implications of these polar Hg events are not restricted to the high Arctic environment.

Table 1. Statistical summary of daily GEM and ozone measurements in Kuujjuarapik, August 1999-April 2001

	GEM (ng·m^{-3})	Ozone (ppbv)
Median	1.78	29.21
Minimum	0.29	1.28
Maximum	3.17	50.2
n	745	765

Figure 2 shows BrO concentrations measured by GOME during the largest GEM and ozone depletion event in Kuujjuarapik on March 15, 2000 (Richter et al. 2000). This period coincided with a large and persistent cloud of vertical columns (BrO ~ 1.00 × 10^{14} molec·cm^{-2}) located over Hudson Bay.

GEM and ozone depletion during an intensive field campaign

During an intensive field research campaign conducted April 14 to 19, 2000, a depletion event was observed on April 15. This event occurred during the night and persisted until twilight of April 16. During this event, both GEM and ozone (Figure 3) were almost removed from the

Figure 1. Daily median GEM and ozone concentrations in Kuujjuarapik, August 1999-April 2001

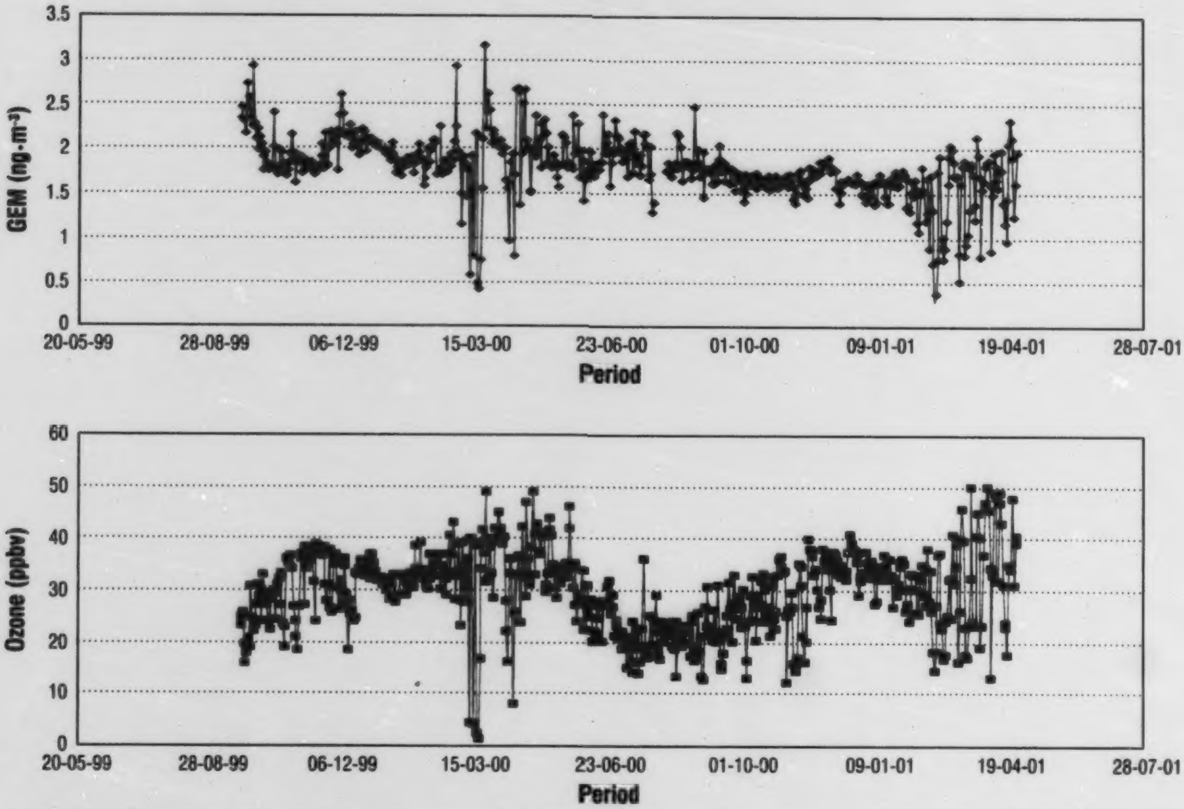
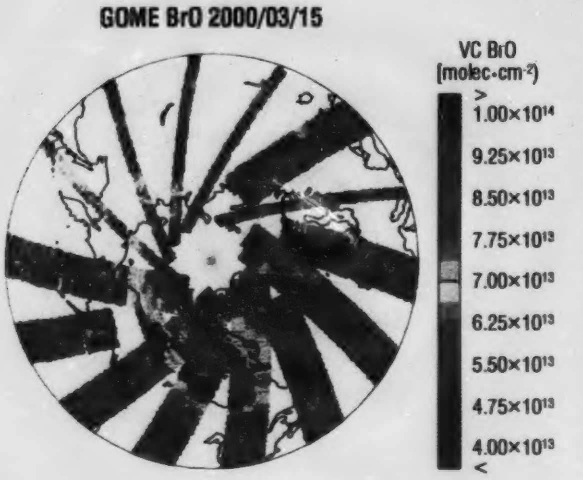


Figure 2. BrO concentration measured by GOME during the largest GEM depletion event (March 15, 2000) in Kuujjuarapik, 2000-2001*



* Source: Richter 2000

surface air (0.25 ng·m^{-3} and 5 ppbv, respectively). The event was also concomitant with a large BrO cloud, as observed by GOME over Hudson Bay (BrO ~ 1.00 × 10^{14} molec·cm^{-2}) (Richter et al. 2000). This observation highlighted night-time chemistry other than photochemical (such as those involved in the polar solar experiment) or atmospheric transport. To fully understand such events, further research would have to be done on such episodes.

Mercury in snow

Mercury snow surveys, done before and after the depletion event, confirmed an increase of Hg concentrations in snow (1600%). These concentrations increased from about 5 ng·L^{-1} on April 13, 2000, to a maximum of 82 ng·L^{-1} on April 16, 2000, (16:00 hours), suggesting an important Hg fallout following the depletion event (Poissant et al. 2001, Amyot et al. 2001). Furthermore, a time series of Hg concentrations in snow (Figure 4) showed a diurnal variation on 2 subsequent days of observation, with maximum concentration late in the afternoon, suggesting slow particle settling. Lots of Hg in snow pack is significant (> 50% within 12 hours) and would result in Hg volatilization to the atmosphere (Poissant et al. 2000).

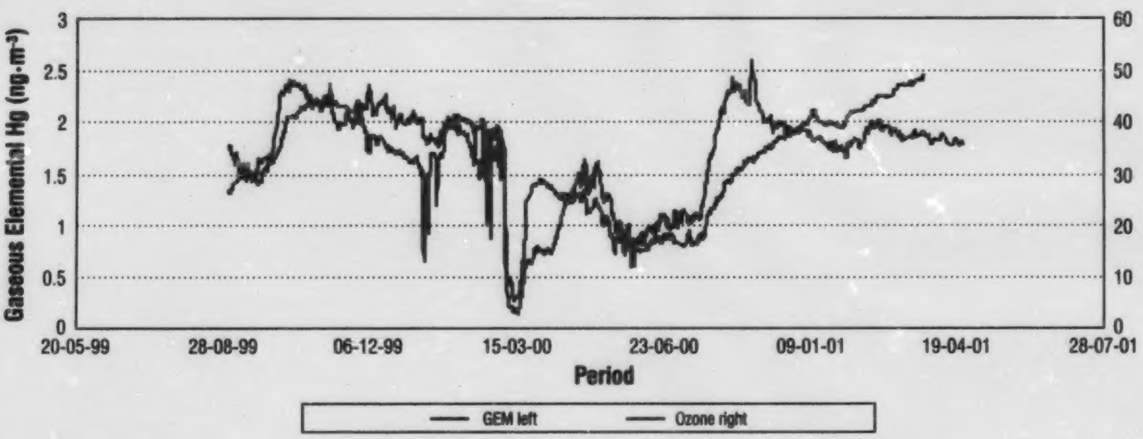
Conclusions

This atmospheric Hg project in Kuujjuarapik is in its second year of development and is part of one of the first studies to conduct atmospheric chemistry measurements in northern Quebec. Important findings were made within this period, 2000-2001. Mercury depletion events are extended over the whole Arctic area in the springtime. Fresh Hg deposition is volatilized further in the days following the depletion event and Hg depletion seems to be connected with BrO episodes.

Expected Project Completion Date

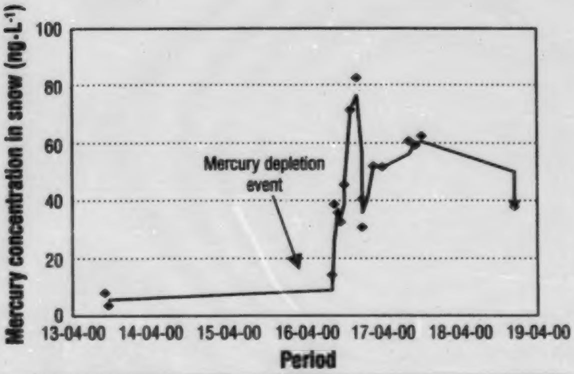
This project is ongoing.

Figure 3. Time series of 15-minute average values for ozone and GEM at Kuujjuarapik, April 14-19, 2000*



* Time is in EDT.

Figure 4. Time series of mercury concentrations in snow in Kuujjuarapik before and after a mercury depletion event



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Mercury Measurements at Alert

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Abstract

Atmospheric mercury measurements have been made at Alert, Nunavut since 1995. This study collects baseline gaseous elemental mercury (GEM) data to study spatial and temporal trends of mercury in the Canadian Arctic. Through this project, a significant discovery was made that sparked international interest. It was found that during the springtime, mercury is transformed from the stable species (GEM) to a much shorter-lived, more reactive species that can have a significant impact on the Arctic environment. To date we have annual data from 1995 to 1999 (quality assured and quality controlled) and have collected data from 2000. As in previous years, the annual GEM data showed distinct seasonal patterns. Snow samples were collected during the winter-spring of 2000 and showed concentrations similar to those collected in the previous 2 years. In the winter of 2001, an automated reactive gaseous mercury (RGM) and particulate mercury (PM) analyzer was installed at Alert to further study the behaviour of mercury in the Canadian Arctic. This instrument will run for a year and will supply the first continuous annual set of RGM/PM data in the Arctic.

Key Project Messages

1. Atmospheric mercury (Hg) measurements have been made continuously at Alert, Nunavut since 1995 and have shown distinct seasonal patterns.
2. The study of Hg depletion episodes and their impact on the Arctic environment is continuing. A new instrument to study various mercury species has been installed at Alert.
3. Snow samples collected at Alert show lower Hg concentrations in the snow during the period when the Arctic receives no sunlight, but significantly increased concentrations once the sun returns in the springtime.
4. This research group participated in an international study at Alert between January and May, 2000 (Alert 2000), where further studies into the behaviour of Hg during the springtime were undertaken.

Objectives

1. To collect baseline ambient air concentration measurements of gaseous elemental mercury (GEM) at Alert, Nunavut, for the purpose of establishing:

  - ambient air concentrations in the Canadian Arctic and their linkage to elevated levels of Hg in the Arctic food chain
  - temporal and long-term trends in the high Arctic
  - emission sources through long-range transport studies, and
  - a scientific information base to use in developing Canadian strategies for international controls.
2. To study the chemical and physical aspects of atmospheric Hg vapour transformations after polar sunrise and the resulting link to enhanced concentrations in the Arctic environment.

Introduction

Mercury is a toxic metal and has been identified as a priority pollutant by various national and international organizations. Levels of Hg in many Arctic wildlife are elevated (Lockhart 1999), creating a concern among northern communities. In 1995, continuous GEM* measurements began in the Canadian Arctic at Alert, Nunavut. Since this time, significant advances in our knowledge of atmospheric Hg in this environment have been made. It was discovered that during the springtime, Hg is transformed from the relatively long-lived stable species (GEM) to a much shorter-lived, more reactive form (Schroeder et al. 1998). It is thought that this conversion of Hg after the polar sunrise may provide a pathway for the introduction of these more reactive Hg species to the Arctic environment and may be impacting large areas of the Northern Hemisphere (Lu et al. 2001).

This Hg measurement program provides long-term data on the spatial and temporal trends of Hg in the Arctic environment. These results can be used in developing and implementing Canadian international strategies, and negotiating positions to achieve appropriate controls for priority pollutants of concern, such as Hg. Results from this program have generated international interest and have resulted in similar measurements being made in Alaska, Norway, Denmark (Greenland) and Russia. These data (Canadian and other) will provide important information on the transport, transformation and deposition processes of this priority pollutant throughout the polar regions.

Activities in 2000-2001

Ground-based atmospheric GEM measurements continued at Alert. The mercury measurement program at Alert continues to be a participant in the Canadian Atmospheric Mercury Measurements Network (CAMNet).

The Cold Regions Pyrolysis Unit (CRPU) operated between February and May 2000. This addition to the Hg vapour analyzer at the Global Atmospheric Watch (GAW) laboratory was used to confirm the presence of non-Hg(0) mercury species in the air at the time of depletion events.

Samples of freshly fallen snow were collected at Alert over a 3-month period during the winter-spring of 2000-2001. These samples were collected on a Teflon covered table and analyzed, using ultra-clean methods for the concentration analysis of total Hg.

Between January and May 2000, our group participated in the Alert 2000 campaign in which our goal was to study ground level Hg depletion chemistry and the potential role that the snow pack and surfaces play in this phenomenon.

In February 2001, an automated reactive gaseous mercury (RGM) and particulate mercury (PM) instrument was installed at Alert to address questions regarding the behaviour of Hg species and aerosols throughout the year.

Results

Ground level measurements were continued for GEM in ambient air at Alert. Data up to August 2000 has been quality assured. GEM concentrations that were submitted to the National Chemistry (NatChem) Database for 1995 to 1999 are shown in Figure 1; results of seasonal data are shown in Figure 2 for 1995-2000. The CRPU was employed to continuously measure total airborne Hg concentrations before and during the springtime depletion episode time period in 2000, similar to what was measured in 1998; results are shown in Figure 3. Mercury concentrations in snow from 1999 and 2000 are shown in Table 1. Freshly fallen snow was collected on Teflon-coated tables near the GAW laboratory (~ 6 km inland). In 2000, some of the snow samples were collected on a table situated 1.4 km north of Ellesmere Island over the frozen Arctic Ocean.

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* The nomenclature has changed over the past year. Previously, Hg(0) was referred to as TGM (total gaseous mercury) since this is the most abundant part of TGM. However, with the continuing research and discoveries of the importance of other Hg species (i.e. reactive gaseous mercury and particulate mercury), Hg(0) is now referred to as gaseous elemental mercury (GEM).

Table 1. Mercury concentrations in snow, 1999 to 2000

				Mean Hg Concentration		
Site	**Year**	**Time of Sample**	**Sample Period**	**($pg \cdot mL^{-1}$)**	**Standard Deviation**	**n**
Inland[1]	1999	DARK	Jan.27-Mar.18	4.9	2.8	25
Inland	1999	LIGHT	Mar.18-May 23	185	635	16
Inland	2000	DARK	Feb.11-Mar.5	5.0	1.2	12
Inland	2000	LIGHT	Mar.5-May 5	121	303	16
Ice[2]	2000	DARK	Feb.15-22	21.7	7.0	4
Ice	2000	LIGHT	May 2-8	182	316	10

[1] Near Environment Canada's Global Atmospheric Watch Site

[2] Over the Arctic Ocean

Discussion

Annual and seasonal GEM

Figure 1 shows 5 years of sequential annual GEM data from Alert. The distinct annual pattern is evident and shows, in general, very little inter-annual variation. This plot also shows the repetitive nature of the pattern of GEM in the Canadian high Arctic. A key issue in this project is the long-term trend of atmospheric Hg in the Arctic. Questions as to whether Hg levels are increasing or decreasing are important to address, yet several more years of data are required to properly establish a trend. The annual data collected at Alert is being used by various groups in assessing transport patterns of Hg, statistical calculations of large data sets, and global and Canadian atmospheric modelling of Hg (e.g. researchers at Oak Ridge National Laboratories, Tennesee, the University of Jena, Germany, and A. Dastoor, MSC). The box and whisker plots, shown in Figure 2, summarize the seasonal variation of GEM from 1995 to 2000. The least variation in concentration levels is seen in the autumn (October to December). This period is thought to be the most representative of northern hemispheric background GEM concentrations (mean: 1.55 ± 0.08 $ng \cdot m^{-3}$). The largest concentration distribution is found in the spring (April to June). This is expected, as it is the time of episodic Hg depletion events and concentrations fluctuate considerably. The winter season shows outliers that are biased to the lower concentration values and the summertime outliers are biased towards the higher values. Every year in the summertime, an increase in the GEM levels is observed; it is thought that the summertime increase is due to an emission of the Hg that was deposited during the depletion periods in the spring.

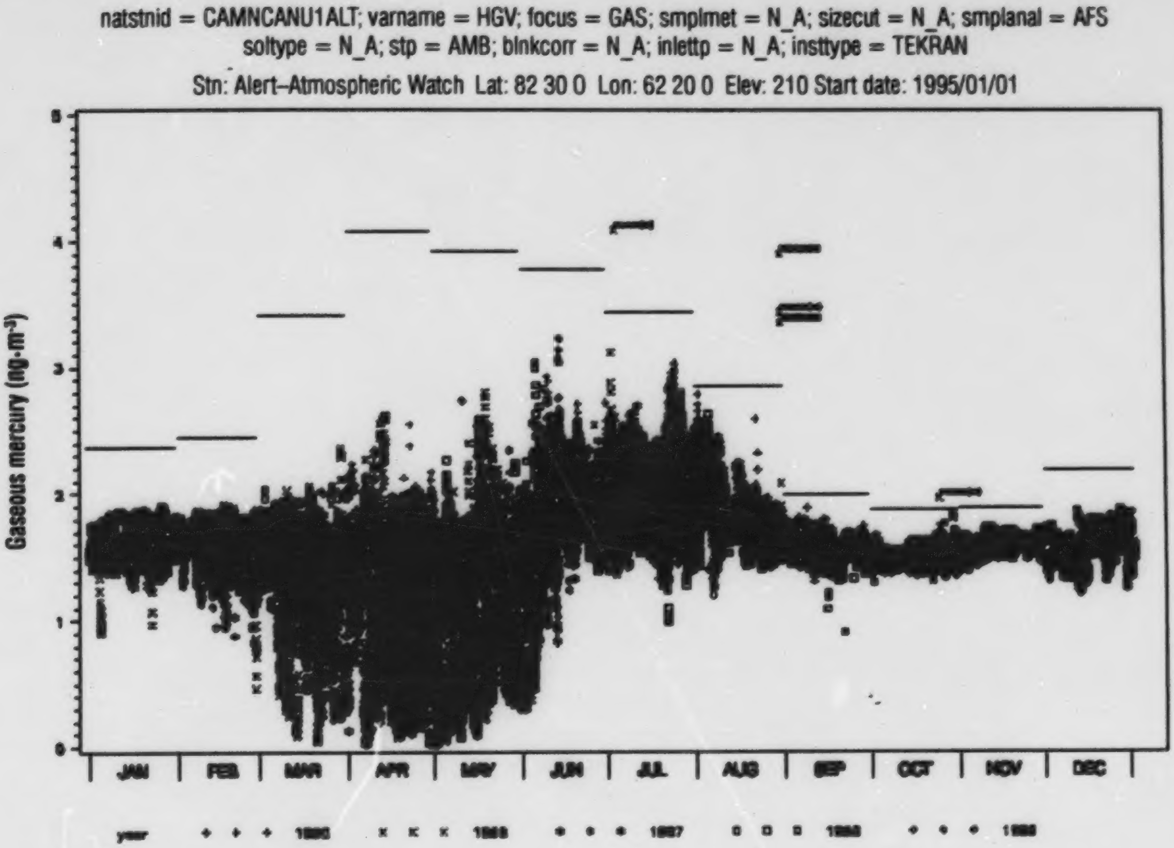
Cold Regions Pyrolysis Unit

The CRPU was employed in 1998 to assess the hypothesis that Hg(0) is converted to other Hg species in ambient air in the springtime at Alert. This assumption was confirmed in the 1998 study but the data were limited since there was only one Hg depletion event during which this unit was employed (Schroeder et al. 1999). Therefore, the experiment was repeated again in 2000. Results from this experiment are shown in Figure 3. The CRPU is a front-end unit through which ambient air is drawn and separated into two different streams. One stream of air is pulled straight into a Tekran Hg vapour analyzer as ambient air. The other air stream is drawn through an unfiltered heated oven (filled with quartz chips retained at 900°C) that pyrolyzes all Hg species in the incoming air to their elemental form and is then detected by the Tekran instrument. The concentrations of Hg from these two streams are then compared. Results show that the two streams track each other well when there is no depletion event, indicating that ambient air consists mainly of Hg(0). When a depletion event occurs, the ambient GEM concentrations drop well below the pyrolyzed air Hg concentrations. This confirms that there is conversion of Hg(0) during a depletion event and that other Hg species are present in the air. It is noted, however, that the entire GEM converted or "missing" from ambient air is not recovered by pyrolysis. Present estimates indicate that pyrolyzing unfiltered air can account for up to 62% of the GEM previously oxidized (using the 2000 data). This result supports the idea that a significant amount of the oxidized Hg in the air during depletion times is unaccounted for. Such oxidized Hg(II) species have higher deposition fluxes than the Hg(0) precursor and, thus, are more readily deposited onto the snow and ice surfaces. Results from freshly fallen snow samples at Alert confirm this.

Mercury in freshly fallen snow

Since 1998, depositional fluxes of Hg in the snow phase have been measured using ultra-clean methods at Alert. In 2000, samples were collected from two sites, one inland and one located on the ice. Sampling at the ice

Figure 1. NAtChem/PM QA Plots for Canadian Atmospheric Mercury Network*



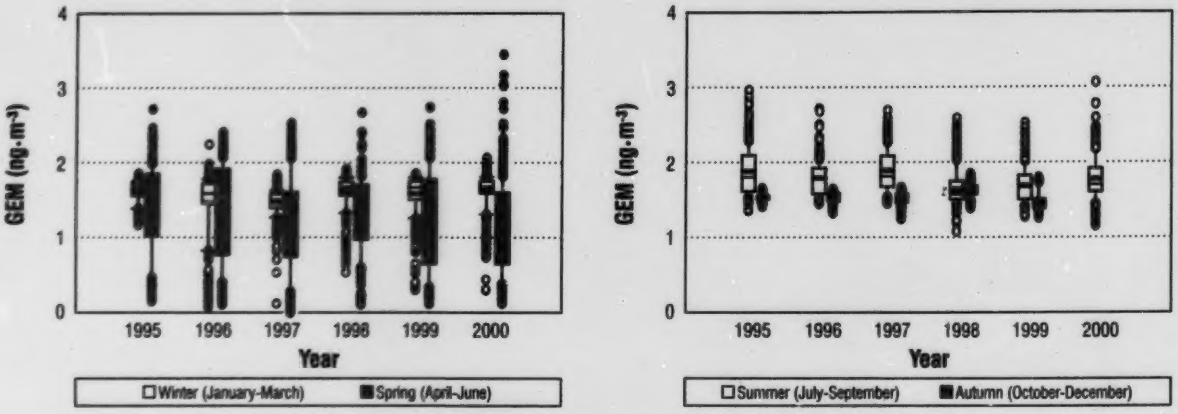
* Solid line indicates monthly mean + 5 standard deviations. Samples with non-conforming periods invalided by NAtChem/PM are not shown in these plots.

site was divided into a dark period sampling time (pre-sunrise) and light sampling periods (post-sunrise). The sunrise period at Alert started around February 29; for the first few weeks, the solar intensity was weak but increased daily. Mercury depletions are infrequent during this initial period. A summary of the results for inland snow concentrations for the 2000 season are shown in Table 1, along with the 1999 results. Pre-sunrise, or dark period, samples for the 2000 year were taken up to March 5, while 1999 dark period results were based on samples taken up to March 19. Light period results represent samples taken after these days. Also shown are the 2000 ice location sample results for both the dark and light periods. At all sites, the concentration of Hg in the snow is significantly higher (up to 37 times) in the light period than the dark period. This indicates that a significant portion of the converted Hg is deposited or scavanged by the snowfall on the ice and snow surfaces during the springtime at Alert. In general, during the light period, the Hg concentration in the snow inland and over the ice are similar but, during the dark period, it was observed that the concentrations over the ice are higher. This could be an indication that the deposition behaviour of Hg is different over the ice than inland and could have a significant impact on the Arctic as a whole. Further investigation into this finding is warranted.

Alert 2000 Campaign

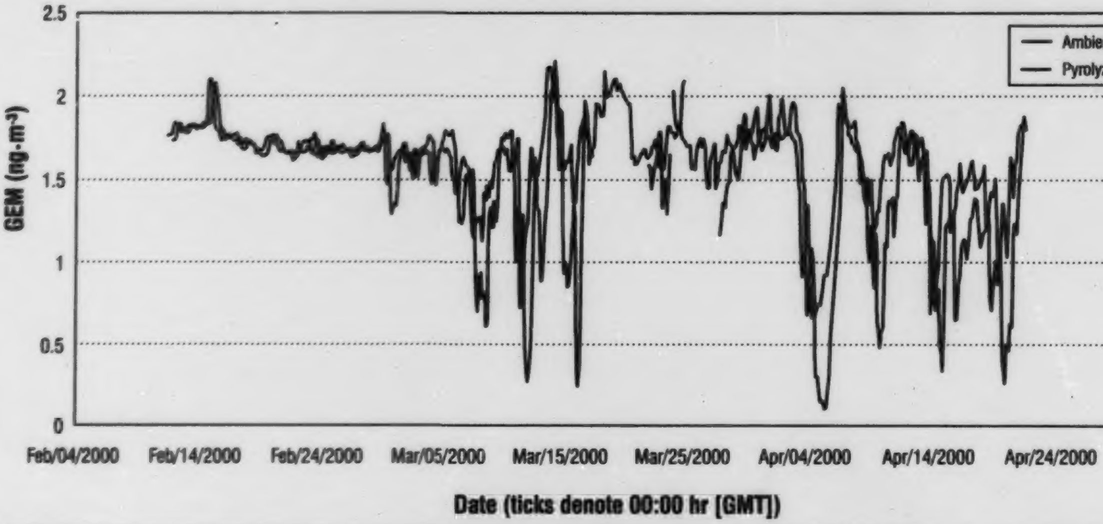
Our group participated in Alert 2000, a large international campaign involving more than 35 scientists from six different countries, between January and May 2000. The goal of this campaign was to study the chemistry in air, snow and ice around the time of the polar sunrise in the Arctic. Various experiments were conducted, both over snow-covered tundra and over frozen ocean. Air-profiling experiments indicate that during Hg depletion events (and for a short period thereafter), Hg is emitted from the snow-pack. Snow-profiling experiments revealed that concentrations of Hg(0) vapour in the interstitial air

Figure 2. Seasonal variation of GEM from 1995 to 2000*



* The plots indicate the median, 10th, 25th, 75th and 90th percentiles as vertical boxes with error bars. The heavy black line marks the seasonal mean value.

Figure 3. GEM concentrations in ambient and pyrolyzed air streams, late winter to early spring, 2000



spaces of the snow pack, which had accumulated during the previous fall and winter months, decreased with increasing depth, with the lowest concentrations existing in the hoarfrost layer immediately above the frozen ground. Some of these findings will be published in a special issue of *Atmospheric Environment* (Steffen et al. 2001).

Conclusions

This unique program is providing considerable data towards understanding the relationship between Hg in the atmosphere and high levels of Hg in the Arctic environment. It is critical that the monitoring of gaseous phase Hg (and ancillary measurements) continues at Alert for the next several years to establish trends and to answer the many posed questions by governments, scientists and communities about this high priority pollutant in the Arctic environment.

Expected Project Completion Date

This project is ongoing.

Acknowledgments

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preparation and analysis. Contributions from Defence Research Establishment Atlantic during the Alert 2000 campaign are greatly appreciated from Jim Milne, Dan Wile, Gary Heard and Ron Verrall. Also, the facilities and assistance from the Department of National Defence and the continuous excellent support of the personnel at CFS Alert have been invaluable and are truly appreciated.

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Mercury Measurements at Amderma, Russia

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Abstract

Mercury in the environment comes from both natural and human-made sources and is found in ambient air in the vapour phase or attached to aerosols. Interest in the study of atmospheric mercury in Arctic environments has grown considerably in the past several years since the discovery of springtime mercury depletion episodes in Alert, Nunavut, and the possible impact that this discovery has on the Arctic environment. Very few, if any, measurements have been made in the Russian Arctic. The measurement of gaseous phase mercury will begin in Amderma, located in the Russian high Arctic, in June 2001. This study, in conjunction with four other polar sites (in Canada, Norway, Denmark and the United States), is intended to assess the not yet fully understood behaviour of mercury in Arctic regions and whether mercury concentration levels are increasing or decreasing. To date, the instrumentation has been installed at the Amderma site, the Russian scientists have been trained on the instrument operation and data is expected beginning June 2001.

Key Project Messages

1. The measurement of gaseous elemental mercury (GEM) has been initiated in Amderma, Russia.
2. Currently, six sites in the Arctic are investigating GEM; the addition of this Russian site will help complete a circumpolar network to measure mercury (Hg) in the Arctic environment.

Objectives

1. Measure continuous GEM concentrations at Amderma, Russia.
2. Investigate and establish temporal (annual, seasonal) variability in GEM concentrations.
3. Study circumpolar behaviour of GEM by comparing data between four different high Arctic sites.
4. Use the data to develop representative models of atmospheric pathways and processes of Hg and potential sources.

Introduction

The Arctic ecosystem is exhibiting increasingly disturbing evidence of contamination by a host of persistent, bioaccumulating toxic substances including heavy metals, such as Hg (Jensen et al. 1997). The atmosphere is the first medium in which to observe trends of pollutants and the effects of various national and international control efforts. By monitoring atmospheric Hg, the effect of these efforts can be observed.

Significant advances in the knowledge of atmospheric Hg in the Arctic environment have been made since the inception of Hg research at Alert, Nunavut. The discovery of the "Arctic springtime depletion of mercury" (Schroeder et al. 1998) laid the foundation for subsequent significant discoveries regarding the transformation and deposition of Hg in the Arctic. It has been found that in the springtime, the annual accumulation rate of Hg in the snow is enhanced by a factor of four (Lu et al. 2001). These discoveries can have profound effects on the Arctic environment and have sparked international interest and scientific investigations into this phenomenon in the Arctic and the Antarctic by various international agencies.

Gaseous elemental mercury is currently being measured at six different international Arctic sites on a routine basis (Alert, Canada; Pt. Barrow, U.S.A.; Svalbard/Spitsbergen, Norway; Station Nord and Nuuk, Greenland; Thorshaven, Denmark) but there is a significant gap of information from the expansive Russian Arctic (see Figure 1). In support of international environmental commitments, such as the Arctic Monitoring and Assessment Programme, Hg is being measured at a site in northern Russia (Amderma, 69ºN, 61ºE). Amderma is also the site for which persistent organic pollutant (POPs) measurements have been made between 1999-2001.

Activities in 2000-2001

In June 2000, a Tekran Hg vapour analyzer, and associated equipment and instrumentation were brought to Obninsk, Russia. This is the location of the scientific team (SPA "Typhoon") that is responsible for the operation in Amderma. The Russian scientists were trained by Environment Canada personnel on the set-up and operation of the equipment. In March 2001, final approval from the Russian authorities to initiate installation of the instrumentation in Amderma was granted. The instruments were installed at the site and, pending the arrival of the instruments' operational gases, collection of data will begin in June 2001.

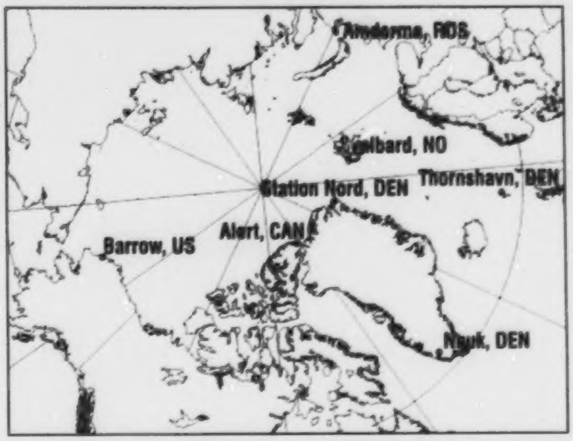
Results

As of May 2001, there has been no data collected. Results will be forthcoming when data collection is initiated.

Discussion and Conclusions

This investigation will greatly enhance the current understanding of the behaviour of Hg in the Arctic environment by providing new information on the spatial extent and temporal transport trends of this toxic metal from northern Russia. This study will fill in gaps of knowledge regarding the distribution of Hg to the Arctic environment as a whole and will provide important information for the development of long-term international strategies for the sustainable development and protection of polar regions. The addition of the Amderma site to the circumpolar network will help close the gaps in knowledge about key atmospheric transport, transformation and deposition processes of this priority pollutant – processes that can lead to contamination of the Arctic ecosystem and traditional food sources for Aboriginal people in Russia and all circumpolar countries. As well, the data generated from this network will help to ascertain whether atmospheric Hg concentrations are increasing or decreasing in the Arctic environment.

Figure 1. Circumpolar map of Arctic sites at which GEM measurements are ongoing



Expected Project Completion Date

This project is expected to continue for 5 years, until March 2005.

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Quantifying and Reducing Uncertainty in Model Calculations of Global Pollutant Fate

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Abstract

Current assessment methods for long-range transport potential of organic chemicals rely on the calculation of a characteristic travel distance or spatial range. A complementary approach uses an existing zonally averaged global distribution model to estimate the potential of a chemical to reach, and accumulate in, the Arctic region. The criterion to quantify this Arctic accumulation potential (AAP) is the fraction of the total global amount in environmental surface media that is accumulated in Arctic surface media after a certain time period. The simulations use hypothetical emission estimates with a generic spatial and temporal distribution. We have used this approach to assess the AAP of a multi-dimensional "space" of hypothetical chemical property combinations. The AAP was found to be determined by highly complex interactions and to be dependent on the partition properties, the degradation rates in atmosphere and surface media, and the mode of emission of a chemical.

Key Project Messages

1. The global distribution model can be employed to identify chemical properties and emission situations that favour accumulation in Arctic ecosystems.
2. The potential of an organic chemical to accumulate in the Arctic is determined by a complex set of processes, but tends to be higher for substances with high volatility (low log K_{OA}) that neither sorb to organic phase (low log K_{OW}) nor are very water soluble (high log K_{AW}), and for substances being emitted into the atmosphere.
3. A very persistent, involatile, yet water-soluble substance (low log K_{AW}) has significant potential to accumulate in the Arctic well after emissions have ceased, due to slow oceanic advection.
4. Model simulations suggest that very hydrophobic compounds (log $K_{OW} > 8$) with intermediate volatility (log $K_{OA} = 7$) may have an extremely high potential for accumulation in polar regions, if persistent and emitted to air. Efforts should be directed to identify chemicals with such properties.

5. Variable persistence of a chemical in air and surface media can either enhance or decrease its potential to become relatively enriched in Arctic ecosystems.

Objectives

The main objective of the project is to describe quantitatively, with model calculations, the global distribution behaviour of persistent organic pollutants (POPs), and to establish credibility in the results of these simulations. Specifically, the following objectives are:

1. Conduct a comprehensive uncertainty analysis of the global model calculations for α-HCH and PCBs to increase credibility in the descriptive and predictive capabilities of the model.
2. Use the global model in an evaluative fashion to investigate the global distribution behaviour of organic chemicals as influenced by (a) their physical-chemical properties, (b) their persistence in various media and climates, (c) hypothetical environmental and (d) emission scenarios.
3. Compare results obtained with the zonally averaged global distribution model with those obtained by other global modelling studies for POPs.

Introduction

For several years we have been developing, improving, and using a zonally averaged global distribution model for POPs (Wania and Mackay 1995). A version for public distribution, called Globo-POP, was released in 2000 (Wania and Mackay 2000) and is posted for downloading on the Web site: www.scar.utoronto.ca/~wania. There are two principal means to employ this global distribution model for POPs: (1) simulation of the observed environmental fate of a specific contaminant using realistic historical emission estimates and environmental parameters; and (2) use of the model in an evaluative fashion using hypothetical emission scenarios, simplified environmental parameters, and sometimes hypothetical chemical property combinations.

The simulations of the historical fate of α-HCH and PCBs, conducted as part of this project in previous years, are examples of the first type of use (Wania 1999, Wania et al. 1999a, 1999b, Wania et al. 2000). The second type of model use can facilitate the identification of chemical property combinations that enhance the potential for long range transport and accumulation in the Arctic. The type of questions that can be addressed are: What chemical property combinations make a chemical most likely to be transported to, and accumulate in, polar regions? Is high persistence or intermediate volatility more important in determining the potential of a chemical for long-range transport? Are there threshold values for these chemical properties beyond which transport to, and accumulation in, polar regions increases substantially? For which chemical property combinations, if any, can we expect a delay between the maximum global release and the occurrence of maximum concentrations in the Arctic? What effect on global transport behaviour does the mode of emission have (i.e. whether the chemical is emitted into air, water or soils)?

Activities in 2000-2001

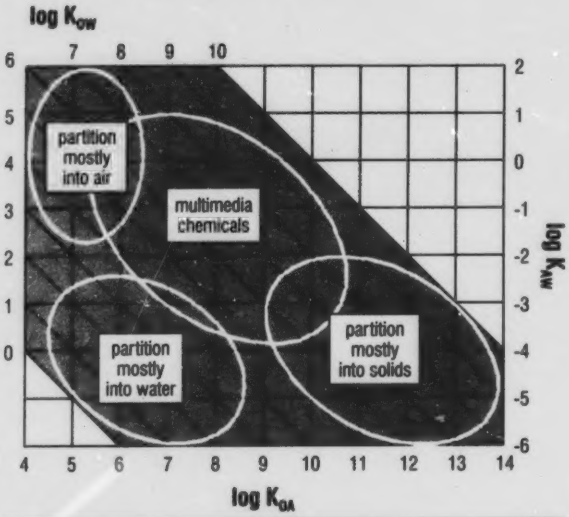
Uncertainty analysis of the global model calculations for α-HCH and PCBs.

A paper on the influence of forests on the overall fate of semivolatile organic substances was published (Wania and McLachlan 2001). This allows for the estimation of the effect of increased deposition to forests on the potential for POPs to reach the Arctic.

Use of the global model in an evaluative fashion to investigate the global distribution behaviour of organic chemicals

The first step in this undertaking was the identification of a suitable model outcome. Of particular interest to the Northern Contaminants Program is predicting a chemical's potential to be transported to Arctic regions and accumulate in the Arctic marine, freshwater and terrestrial environments. Accordingly, we identified the Arctic accumulation potential (AAP) as the model outcome of principal interest and defined it as the fraction of the total global amount in environmental surface media (i.e. the environmental media other than the atmosphere) that is accumulated in the surface media of the North polar model zone. However, that fraction depends on a number of model parameters, most notably the duration and location of chemical discharge to the global environment. Unless steady state conditions are assumed (which would be inappropriate on a global scale), the AAP is also a function of time. Therefore, it is assumed that for calculations of the AAP, the emission of a chemical occurs steadily for 1 year (January 1 to December 31) with a zonal distribution that reflects the global population distribution. The AAP is calculated at the end of 1 year of emission, and again after an additional nine years without emissions have passed. The first fraction is termed AAP_1 and reflects the AAP of a currently emitted substance. The second is termed AAP_{10} and describes the potential for long-term Arctic accumulation after emissions have ceased. Using these definitions of AAP, we calculated AAP_1 and AAP_{10} for numerous hypothetical

Figure 1. Range of physical-chemical property combinations being simulated



physical-chemical property combinations (see Figure 1 for the range of physical-chemical property combinations being simulated) of a perfectly persistent chemical. These calculations were undertaken for emissions to air, water and soil. We also calculated AAP_1 for chemicals that undergo environmental degradation assuming variable rates of transformation in atmosphere and surface media.

Comparison of results obtained with the zonally averaged global distribution model with those obtained by other global modelling studies for POPs

In line with the focus on identifying the AAP of organic chemicals, it was decided to start the comparison of our global distribution model with the model by Scheringer et al. (2000) by comparing estimates of the potential for cold condensation (cc) at the poles, as defined by Scheringer et al. (2000). These authors express the extent of accumulation at the poles by calculating the ratios of the exposure values at the poles, e_1 and e_n, to the minimal exposure values of both hemispheres, thus $cc_N = e_1/e_{N,min}$ and $cc_S = e_n/e_{S,min}$ for the northern and southern hemisphere, respectively. Exposure in this context is defined as a time-integrated concentration in the various model compartments, weighted according to their volume fractions. In the global distribution model, the number of zones is fixed at 10, so that $cc_N = e_1/e_{1\ to\ 4,min}$ and $cc_S = e_{10}/e_{6\ to\ 9,min}$. Scheringer et al. (2000) used hypothetical short pulse emissions in the estimate of cc_N. For PCBs and α-HCH, we can also calculate the time-integrated exposure, and thus the cold condensation ratios, cc_N and cc_S, for realistic decade-long emission estimates.

Results

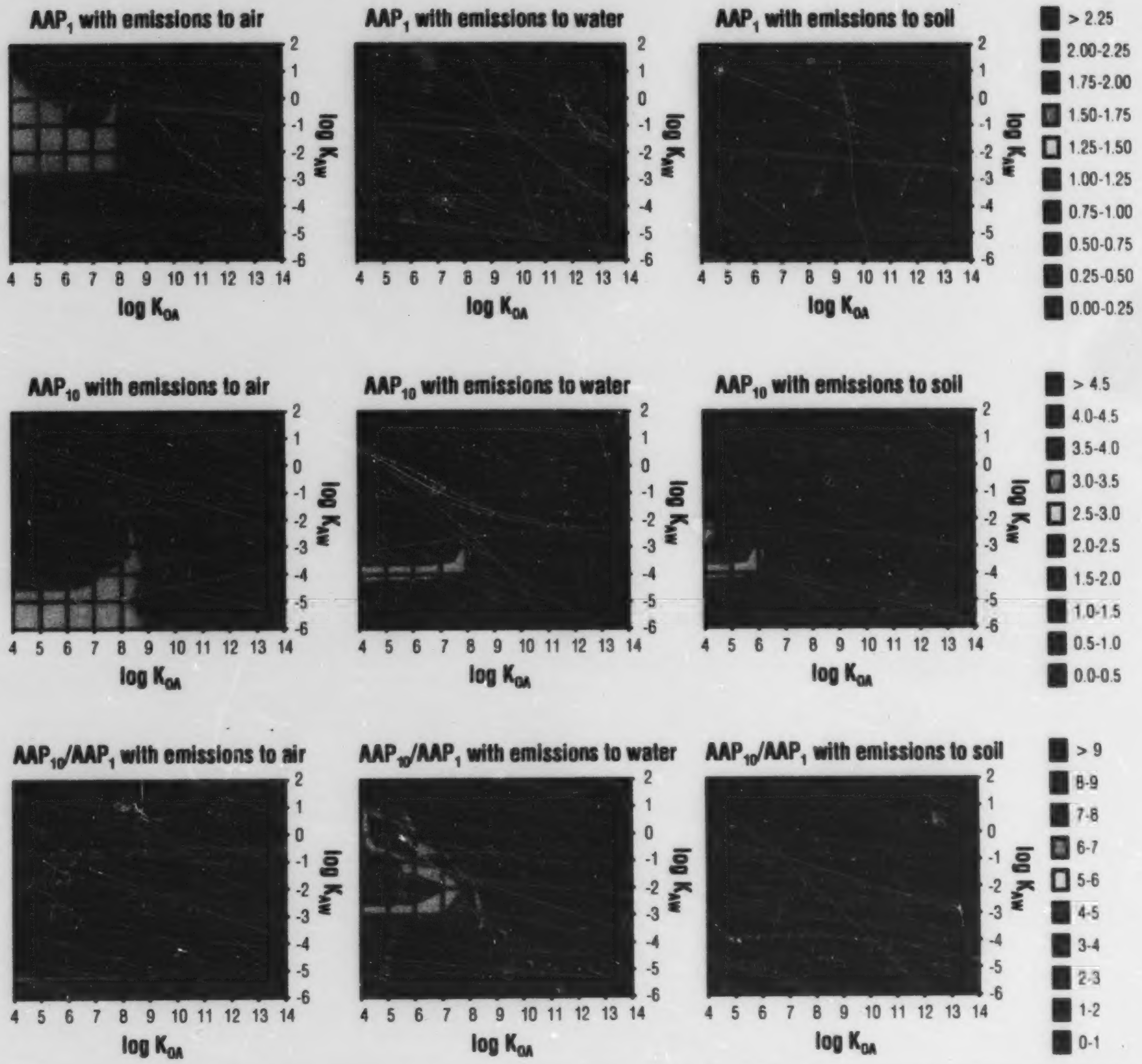
Only a few select results can be presented within the limits of this report. Figure 2 displays the calculated AAP for perfectly persistent chemicals, with emissions occurring either entirely into air (graphs in the left column), water (middle column) or soil (right column). The graphs display AAP_1 (graphs in top row) and AAP_{10} (second row) in percent as a function of log K_{OA} and log K_{AW} (i.e. the partitioning coefficients between octanol, air and water). The chemical space thus defined includes virtually all persistent organic chemicals (see Figure 1). A red colour in these graphs indicates a high potential for accumulation in the Arctic surface media; a green colour indicates a low potential. The graphs in the bottom row of Figure 2 compare the AAP calculated for 1 year and 10 years. A red colour in these graphs indicates a potential for long-term accumulation potential, even after emissions have ceased.

Figure 3 shows the effect of variable persistence on the AAP of one physical-chemical property combination (log $K_{AW} = -2$, log $K_{OW} = 5$, log $K_{OA} = 7$, corresponding to a small PCB congener). Displayed is the AAP_1 for a chemical with a reference reaction rate with atmospheric hydroxyl (OH) radicals of k_{Aref}, whereby k_{Aref} is varied from 10^{-11} to 10^{-15} $cm^3 \cdot s^{-1}$, and a reference degradation half-life in surface media of HL_{ref}, whereby HL_{ref} varies from 87.6 hours (a few days) to 876 000 hours (100 years), divided by the AAP_1 of a perfectly persistent chemical with the same partitioning properties. These ratios are shown for emissions to air, water and soil, respectively. A yellow colour in these graphs indicates no change in AAP_1 as a result of variable persistence, a green colour indicates a decrease, and an orange colour an increase in AAP_1.

Discussion and Conclusions

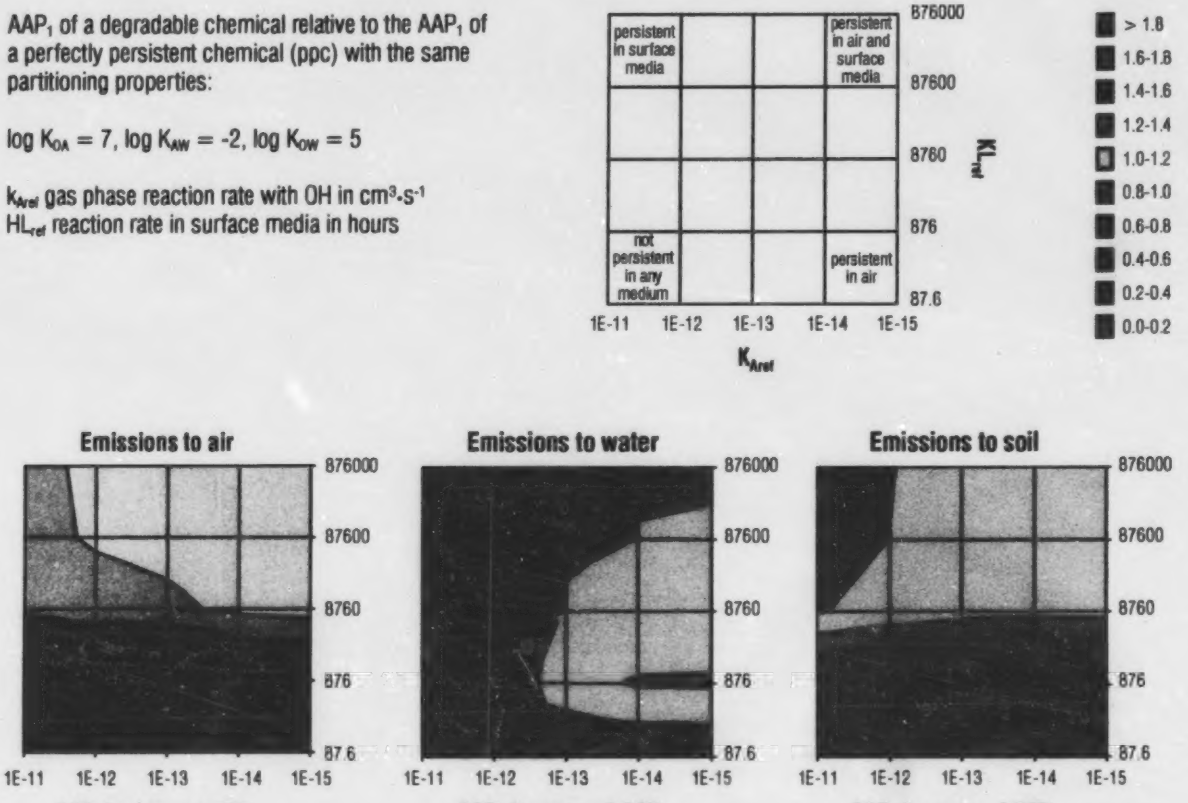
The graphs in Figure 2 show a contour map of AAP as a function of partitioning properties. Steep "slopes" on these maps (i.e. closely spaced contour lines) indicate threshold values where large changes in AAP occur for small changes in partitioning coefficients. A horizontal threshold indicates a change with air-water partitioning properties (with very water soluble substances at the bottom), a vertical threshold indicates a change with octanol-air partition coefficients (with very volatile substances on the left), and a diagonal threshold indicates a dependence on the octanol-water partition coefficient (with very hydrophobic substances on the upper right). All three types of thresholds occur, indicating that the potential for Arctic accumulation is the result of a complex interaction of processes, which depend on the partitioning into air, water and organic phases. An interpretation of the graphs in Figure 2 suggests:

Figure 2. The calculated AAP for perfectly persistent chemicals, with emissions occurring either entirely into air (graphs in the left column), water (middle column) or soil (right column)



- Generally, a "wedge" of high AAP$_1$ appears on the left side of the chemical space (i.e. at low K_{OA} values). The vertical and diagonal thresholds defining the wedge suggest that the AAP$_1$ increases with increasing log K_{AW} and decreasing log K_{OW}. An AAP$_1$ of > 1% is calculated for chemicals with log $K_{AW} > -4$ and log $K_{OW} < 6$, if they are emitted into air. Perfectly persistent chemicals with the partitioning properties of DDT, HCHs, toxaphene, PCBs and HCB have an AAP$_1$ of > 1%.
- The AAP$_1$ is reduced considerably if emission occurs into water or soils. The thresholds for an AAP$_1$ of 1% shift towards log $K_{AW} > -2.5$ and log $K_{OW} < 3$ (i.e. log $K_{OA} < 6.5$) for emissions to water, and to log $K_{AW} > 2$ and log $K_{OW} < 1$ for emissions to soil. The latter condition can only be fulfilled for very volatile chemicals with a log $K_{OA} < 4$.
- An anomaly with extremely high AAP$_1$ of up to 2.5% occurs for air-emitted chemicals with a log K_{OA} of 7 and a log K_{AW} of > 0 (i.e. the chemical needs to have a log K_{OW} of around 8 or higher). This combination of partitioning properties (extremely hydrophobic, but intermediate volatility) is highly unusual, but may actually exist for selected synthetic substances such as some organosilicone compounds. If emitted into

Figure 3. The effect of variable persistence on the AAP of one physical-chemical property combination ($\log K_{AW} = -2$, $\log K_{OW} = 5$, $\log K_{OA} = 7$, corresponding to a small PCB congener)


AAP$_1$ of a degradable chemical relative to the AAP$_1$ of a perfectly persistent chemical (ppc) with the same partitioning properties:

$\log K_{OA} = 7$, $\log K_{AW} = -2$, $\log K_{OW} = 5$

k_{Aref} gas phase reaction rate with OH in $cm^3 \cdot s^{-1}$
HL_{ref} reaction rate in surface media in hours

AAP$_1$ for ppc = 1.40% **AAP$_1$ for ppc = 0.84%** **AAP$_1$ for ppc = 0.07%**

water or soil, these substances show no unusual global transport behaviour because their high hydrophobicity keeps them retained in soils or aqueous sediments.

- If sufficiently persistent, many chemicals can show a delayed AAP, as indicated by the more intense and larger wedges in the AAP$_{10}$ maps. A high AAP$_{10}$ of > 4% is predicted for substances with a $\log K_{AW} > -2.5$ and a $\log K_{OW} < 4$ (i.e. $\log K_{OA} < 6$). The differences between the different emission media are much smaller than for AAP$_1$, suggesting that even chemicals emitted to surface media can have high AAP if given sufficient time. Whereas the AAP$_{10}$ maps are very similar for emissions to air and water, chemicals emitted to soil need to have a fairly high volatility (i.e. have a $\log K_{OA}$ < around 6) to have a high AAP$_{10}$.
- Independent of the medium receiving the emissions, the strongest increase in AAP over the 9 years without emissions (as expressed in a high AAP$_{10}$/AAP$_1$ ratio) is noted for substances with very low K_{AW} (i.e. very water soluble substances). This is due to long-range transport in the oceans.

The total amount of a chemical in the total global environment and the Arctic surface media is obviously smaller if a chemical is no longer assumed to be perfectly persistent. However, the AAP may actually increase, decrease, or stay the same, if the chemical is assumed to degrade in the atmosphere or the surface media or both. It turns out that the effect of degradation on the AAP is not a simple one, but depends on both the physical-chemical partitioning characteristics of the chemical and the mode of its emission into the environment. As an example, the AAP$_1$ of the chemical in Figure 3 emitted to air is at a maximum of around 2.7% if it has an intermediate reaction rate with OH radicals around 10^{-13} $cm^3 \cdot s^{-1}$ and a degradation half-life in the surface media in the range of months. If assumed perfectly persistent, the AAP$_1$ was only 1.4%. If emitted into water or soil, different degradation properties lead to an enhancement of the AAP$_1$ of that chemical. Similar maps have been drawn showing the dependence of the calculated AAP on persistence for other physical-chemical property combinations, revealing that the dependence of AAP on persistence in air and surface media is very different for chemicals with different partitioning properties. Obviously AAP_{10} calculations are not meaningful for non-persistent chemicals, as most of the chemical will have degraded after 9 years without emissions.

In an additional set of calculations, we varied the seasonality, length and zonal distribution of the emissions, and explored the effect on the calculated AAP. The closer the emissions occur to the North-Polar zone, the larger the AAP.

Expected Project Completion Date

July 2002

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Monitoring the Health of Arctic Peoples and Ecosystems and the Effectiveness of International Controls

Part B: Biotic Monitoring

Assessment of Organochlorine and Metal Levels in Canadian Arctic Fox

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Abstract

The Arctic fox is a circumpolar species that is widely distributed across northern Canada. The food habits of the Arctic fox differ between summer and winter, and between inland and coastal/island environments. Results from stable isotope analyses of Arctic fox samples from Ulukhaqtuuq (Holman), Northwest Territories, show that trophic position (as inferred from stable nitrogen values) of Arctic fox is positively correlated with increasing stable carbon isotope values, suggesting that Arctic fox feeding from the marine environment occupy a higher trophic level. However, comparison of stable isotope data with organochlorine (OC) concentrations indicates that trophic position may not influence OC levels for all major OC groups. Preliminary results suggest that while OC levels are highly variable, Arctic fox from Ulukhaqtuuq may be exposed to OC levels above the lowest-observed-adverse-effect levels for adverse effects on mammalian reproduction. Further research is required to properly elucidate the potential wildlife health risk from OC exposure to this species.

Key Project Messages

1. Stable isotope data suggest that Arctic fox feeding from the marine environment occupy a higher trophic level than those feeding further inland.
2. Trophic level may not influence residue levels for all major organochlorine (OC) groups.
3. Preliminary results suggest that Arctic fox from Ulukhaqtuuq (Holman) may be exposed to OC levels above toxicological thresholds for mammalian reproduction.

Objectives

1. Determine tissue residue levels of OCs and metals in Arctic fox feeding in or near an Arctic coastal environment.
2. Assess whether or not residue levels found in Arctic fox pose a potential wildlife health risk.
3. Determine residue levels and assess potential wildlife health risk to wolverines feeding in or near a coastal environment, as part of a pilot project.

Introduction

The Arctic fox (*Alopex lagopus*) is a circumpolar species that is widely distributed across northern Canada (Banfield 1987). It is one of the most economically important species of the Canadian Arctic because of its valuable pelt (Banfield 1987, Hiruki and Stirling 1989). Large numbers are harvested in both coastal and inland communities with communities such as Qamanittuaq (Baker Lake), Salliq (Coral Harbour) and Arviat each trapping hundreds of animals annually (Gamble 1987). Residents of Holman report eating Arctic fox meat when the animals look healthy (Kassam 1999).

The Arctic fox is one of the few species which constitutes an important component of both the terrestrial and marine ecosystems (Hiruki and Stirling 1989). Generally, the diet of the Arctic fox consists of small mammals such as lemmings, Arctic hares and ground squirrels – as well as the eggs and fledglings of ground-nesting birds such as geese, ducks, ptarmigan and seabirds (Banfield 1987). However, the food habits of the Arctic fox in winter are necessarily different from those in summer, based on the seasonal distribution and abundance of available prey species (Chesemore 1968, Fay and Stephenson 1989). As well, there are distinct differences in the summer and winter diets of inland and coastal/island foxes (Chesemore 1968). On land, Arctic foxes feed mainly on lemmings, birds and their eggs as well as scavenge on caribou remains (Chesemore 1968, Kennedy 1980, Garrott et al. 1983, Stickney 1991, Fay and Stephenson 1989, Smits et al. 1989, Bantle and Alisauskas 1998, Kapel 1999). Coastal foxes will also eat marine invertebrates (Fay and Stephenson 1989, Kapel 1999) and fish (Banfield 1987) in summer. In winter and spring on the sea ice, Arctic foxes scavenge the remains of ringed seals and bearded seals killed by polar bears (Stirling and Smith 1977, Andriashek et al. 1985, Fay and Stephenson 1989, Hiruki and Stirling 1989, Kapel 1999) and they will also actively prey on newborn seal pups (Smith 1976, Andriashek et al. 1985, Lydersen and Gjertz 1986). Arctic foxes are quite capable of swimming considerable distances (Banfield 1987, Quinlan and Lehnhausen 1982, Strub 1992) allowing them access to ice floes where marine mammal carcasses may be found.

Stable isotope analyses can be used to distinguish populations feeding at different trophic levels, and in a marine versus a terrestrial/freshwater environment. In single system studies, it is possible to use stable-nitrogen ratios ($^{15}N/^{14}N$) to delineate trophic relationships (Hobson and Welch 1992) since these ratios increase by regular increments from one trophic level to the next (Peterson and Fry 1987). Measurements of naturally occurring stable isotopes in foodwebs can also be used to delineate relative inputs from freshwater and marine biomes (reviewed by Hobson et al. 1997). This is based on the fact that stable isotopes of carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$), sulfur ($\delta^{34}S$) and hydrogen (δD) are typically enriched in marine as compared to terrestrial/freshwater systems and these isotopic signatures are passed on to consumers.

Arctic foxes on Svalbard in the Norwegian Arctic feed mainly on reindeer, ptarmigan and seabirds with seals being regionally scavenged in late winter (Prestrud 1992, Frafjord 1993). Arctic foxes from Svalbard contained high levels of polychlorinated biphenyls (PCBs) (8 mg·kg^{-1} in adipose tissue) (Skaare 1996) which are comparable to mean PCB levels of 8.3 mg·kg^{-1} in fat of foxes on the Norwegian mainland (Wang-Andersen et al. 1993). PCB congener patterns are similar to those found in polar bears and there appear to be no significant differences in PCB levels between the sexes or with age (Wang-Andersen et al. 1993). There does, however, seem to be a negative correlation between PCB levels and the amount of body fat suggesting a "dilution" of PCBs in heavier animals (Wang-Andersen et al. 1993). Comparison of PCB levels in Arctic foxes with earlier data (Norheim 1978) shows that levels remained unchanged from 1973-1974 to 1983-1984 (Wang-Andersen et al. 1993). Based on a review of the literature, Kamrin and Ringer (1996) suggest that fat concentrations above 10 mg·kg^{-1} are linked to reproductive impairment in mammals. Given that the mean PCB levels in Norwegian foxes was about 8 mg·kg^{-1} with some individuals having up to 41 mg·kg^{-1} in the fat (Wang-Andersen et al.

1993), this would suggest that toxic effects, particularly related to reproduction, may be a concern for Arctic foxes.

Activities in 2000-2001

As part of a project, Human and Chemical Ecology of Arctic Pathways by Marine Pollutants, being conducted in Ulukhaqtuuq as well as in communities in Alaska, one of the principal investigators (D. Muir) made arrangements for sampling of Arctic foxes trapped at Ulukhaqtuuq during the November to March 1999-2000 trapping season. The reason for this was that, at Ulukhaqtuuq (Holman), the only Canadian location of the project, consultations and interviews with community members indicated that a variety of other animals besides marine mammals and fish were important to their community, including Arctic foxes. The National Oceanic and Atmospheric Administration/ Cooperative Institute for Arctic Research project was largely directed at analysis of marine biota and did not include land animals such as Arctic foxes.

The Arctic foxes from Ulukhaqtuuq have been analyzed for organic compounds. A total of 100 PCB congeners and 30 OC pesticides and related compounds were quantified by gas chromatography-electron capture detector (GC-ECD) using a series of authentic external standards. Toxaphene was analyzed by GC-electron capture negative ion mass spectrometry using selected ion monitoring (Swackhamer et al. 1987, Glassmeyer et al. 1999) on a HP 5973 mass spectrometer detector. Toxaphene was quantified using a single response factor based on technical toxaphene and 24 chlorobornane congeners were quantified separately using authentic standards.

During the winter of 2000-2001, 50 carcasses of Arctic foxes were collected with the help of local hunters and trappers from each of two communities: one coastal community (Arviat) and one inland community (Qamanittuaq [Baker Lake]) for comparative purposes. The samples collected from Arviat will complement information collected for the second coastal community (Ulukhaqtuuq) in 1999-2000.

Also, a large collection of wolverine carcasses collected from the coastal community of Qurluqtuuq (Coppermine) is available from Government of the NWT (B. Elkin). Information on age, sex, morphometrics, pathology, etc. for these animals has already been documented. Carcasses of 12 wolverines (six adult males, six adult females) collected from Qurluqtuuq (Coppermine) during 1999-2000 have been shipped to the NWRC for analyses of mercury (Hg) and a suite of metals including selenium (Se) and silver (Ag) in liver, and cadmium (Cd) in kidney. Subsamples will be sent to the National Water Research Institute (D. Muir) for OC and toxaphene analyses, as well as stable isotope analyses. Samples were received late in the fiscal year and therefore have not yet been analyzed.

Results

As a pilot study, 20 Arctic foxes collected from Ulukhaqtuuq during the period November 1999 to March 2000 were aged, sexed and analyzed for PCBs and persistent OC pesticides as well as stable isotopes ratios of carbon and nitrogen (Table 1).

Stable nitrogen isotope values were positively correlated with increasing stable carbon isotope signatures. Stable isotopes have been used to assign trophic status of biota and could provide insight into bioaccumulation of OCs into marine zooplankton. The $^{15}N/^{14}N$ isotope ratio in biota increases in a predictable manner between trophic levels (Kelly 2000) allowing trophic positions and OC concentrations to be interpreted along a continuous variable. Carbon isotopes ($^{13}C/^{12}C$) are not enriched significantly between trophic positions and can be used to evaluate energetic pathways between regions with differing carbon sources. As a result, stable carbon isotope signatures can differentiate an organism's dependence on inshore/ benthic and offshore/pelagic regions (Kidd 1998). Our findings demonstrate that the trophic position of Arctic foxes from Ulukhaqtuuq, NWT, is positively correlated with an increasing stable carbon signature ($[^{13}C/^{12}C] = 1.26\,[^{15}N/^{14}N] + 40.29$, $r^2 = 0.55$, $p = 0.002$). This suggests that as the Arctic fox population shifts its feeding dependence (or carbon source) from the terrestrial/ freshwater systems to the marine environment, its relative trophic position significantly increases.

PCBs and chlordane-related compounds were the major OCs present in Arctic foxes (Table 1). While mean levels of all major OC groups were < 100 ng·g^{-1} wet weight there were a few animals with very high levels of oxychlordane, the persistent metabolite of chlordane. Age of the animals ranged from < 1 to 6 years with most being about 1 year old. Concentrations of several OC groups in both liver and muscle samples were found to be positively correlated with increasing trophic position based on $^{15}N/^{14}N$ values ($p < 0.05$ for all comparisons). ΣHCH had the strongest positive relationship with trophic position ($p < 0.001$, $r^2 = 0.618$) (Figure 1). The low correlation coefficient (r^2) between OC concentration and trophic position for all major OC groups suggests, however, that the relationship between OC levels and trophic position is weak.

On a lipid basis the concentrations of OCs are quite elevated. For example, ΣPCBs in liver ranged from 140 to

Table 1. Geometric mean and range of concentrations (ng·g^{-1} wet wt) of major organochlorines groups in Arctic fox liver and muscle samples from Ulukhaqtuuq (Holman), NWT[1]

Tissue	Lipid (%)	length (cm)	$\delta^{13}C$	$\delta^{15}N$	ΣPCB	ΣDDT	ΣCHL	ΣHCH	ΣCBz	TOX
Mean liver	7.9	81	n.a.[2]	n.a.	71.9	2.2	75.8	6.7	2.4	17.1
Minimum liver	3.8	72	n.a.	n.a.	12.0	0.2	5.6	0.6	0.6	0.1
Maximum liver	23.5	91	n.a.	n.a.	816	11.3	1980	32.6	19.1	78.3
Mean muscle	5.0	81	-4.5	9.3	36.1	1.2	20.1	3.9	1.4	4.5
Minimum muscle	1.4	72	-26.5	6.3	6.6	0.1	3.6	0.6	0.4	0.1
Maximum muscle	11.2	91	-22.6	12.8	154	8.5	158	15.7	5.3	20.8

[1] n = 20 for each tissue

[2] Not analyzed

14,600 ng·g^{-1} (lipid wt) and from 97 to 8090 ng·g^{-1} (lipid wt) in muscle. These ΣPCB concentrations are within the range found for Arctic foxes in Svalbard (Wang-Andersen et al. 1993).

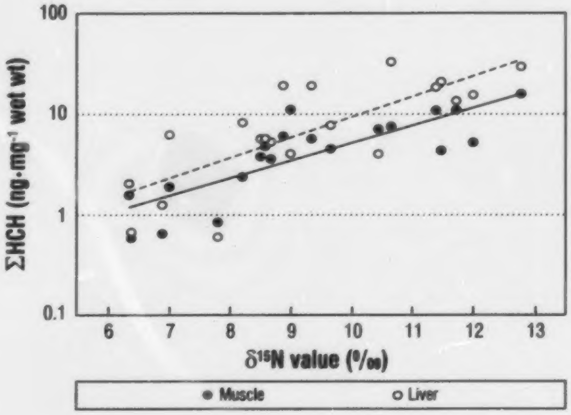
Residue data for the wolverine samples are not yet available.

Discussion and Conclusions

The stable isotope data suggest that increasing trophic position of Arctic fox sampled in this study is directly correlated with an increasing influence of marine dietary influence. However, most OC levels for sum-groups (i.e. ΣDDT, ΣPCBs, ΣCHL, etc.) were not strongly correlated to trophic position. It has been suggested that Arctic fox may be exposed to PCB levels indicative of adverse effects on mammalian reproduction (Brustrom and Halldin 2000). Brustrom and Halldin (2000) observed that PCB levels in Arctic fox liver samples from Svalbard (1993-1994, n = 20) were above the lowest observed adverse effect level (LOAEL) value for reproductive impairment in mink (*Mustela vison*). In some cases, observed PCB levels were above the EC_{50} value for PCB-induced reproduction inhibition. PCB liver concentrations in Arctic fox from Ulukhaqtuuq are generally lower than the levels associated with LOAEL for negative reproductive effect in mink. However, the high abundance of chlordane-related compounds and metabolites suggests that the additive effect of OC contaminants may be underestimated or ignored by considering only those effects induced by PCB exposure.

Additional OC (including coplanar PCBs) and heavy metal analyses are planned for the upcoming year. Liver and muscle samples from Ulukhaqtuuq will be analyzed for Hg and a suite of metals including Se and Ag in liver, and Cd in kidney by Lara Dehn (Ph.D. Candidate) at University of Alaska Fairbanks (Institute for Arctic Biology).

Figure 1. δ^{15}Nitrogen isotope ratios versus ΣHCH in Arctic fox by tissue*



* Relationship for muscle (solid line; log HCH = 0.175 δ^{15}N – 1.04; $r^2 = 0.67$) and liver (dashed line; log HCH = 0.204 δ^{15}N – 1.07, $r^2 = 0.59$) samples

Additional analyses of metals will be carried out at NWRC laboratories for QA/QC purposes.

Expected Project Completion Date

The project should be completed by March 2003.

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Assessment of Spatial and Temporal Patterns of HCH Isomers in the Arctic Environment

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Abstract

The objectives of this study are to compare the spatial and temporal trends of hexachlorocyclohexane (HCH) isomers in biotic and abiotic samples. During the first year of this project, trends of HCH data in Arctic biota (thick-billed murre (*Uria lomvia*) and ringed seals (*Phoca hispida*)) were examined; HCH concentrations, including β-HCH, were determined in water from the eastern Archipelago of the Canadian Arctic; and Henry's law constants (HLC) were determined for α-, γ- and β-HCH. Spatial trends in the relative proportions and concentrations of HCH isomers were observed in the thick-billed murres and ringed seals, although the patterns did not follow any discernable geographic trends. Temporal trends varied among the HCH isomers and among stocks of ringed seals. α-, γ- and ΣHCH concentrations declined in ringed seals from Hudson Bay but not Holman Island between the 1980s and early 1990s. β-HCH has not declined in ringed seals between the 1980s and 1990s, although recent data suggest the start of a decline. Concentrations of α-HCH and γ-HCH are significantly declining while β-HCH is increasing in eggs of thick-billed murres. The variability in spatial and temporal trends between HCH isomers in biota suggests that using ΣHCH is not appropriate for assessing these chemicals in the Arctic. Concentrations of α- and γ- HCH in eastern Archipelago ocean water are similar to past work, β-HCH concentrations are an order of magnitude lower than α- and γ-HCH. The HLC value determined for β-HCH is 10 times lower than α- and γ- HCH. This lower HLC would delay the transport of β-HCH to the Arctic and may in part explain the delay in β-HCH decline in the Arctic.

The Arctic water concentrations and HLC values are among the first reported for β-HCH.

Key Project Messages

1. There are spatial trends in the relative proportions and concentrations of hexachlorocyclohexane (HCH) isomers in ringed seals and thick-billed murres from the Canadian Arctic. However, these trends do not follow geographical patterns and may be confounded by differences in collection years and feeding habits at different sites.
2. Temporal trends in HCH isomer concentrations in ringed seals vary among stocks. α-, γ- and ΣHCH concentrations declined in ringed seals from Hudson Bay but not Holman Island between the 1980s and early 1990s. β-HCH has not declined in ringed seals between the 1980s and 1990s, although recent data suggest the start of a decline. Concentrations of α-HCH and γ-HCH are significantly declining while β-HCH is increasing in eggs of thick-billed murres.
3. β-HCH concentrations in Arctic marine water are an order of magnitude lower than γ-HCH and two orders of magnitude lower than α-HCH.
4. The Henry's law constant (HLC) for β-HCH (HLC = 0.036) is approximately 10 times lower than those of α- and γ- HCH.

Objectives

- To assess the spatial and temporal patterns of the α-, β- and γ- isomers of HCH in the Arctic biotic and abiotic environment, specifically:

1. Compare concentrations and ratios of HCH isomers over time in air, water, seals and seabirds to determine any shifts in isomeric ratios and how those shifts interrelate among the various media.
2. Compare concentrations and ratios of HCH isomers spatially in the abiotic and biotic media and explore reasons for any patterns.

Introduction

HCHs are pesticides that have been manufactured as two predominant products: technical HCH (60% to 70% α-HCH, 10% to15% γ-HCH, 5% to12% β-HCH) and lindane (γ-HCH). Only γ-HCH displays significant insecticidal properties although β-HCH (Willett et al. 1998) and α-HCH have been shown to disrupt endocrine processes (Kendall et al. 1998). The key physical properties that control the ultimate fate of HCH in the environment are high volatility, low Henry's law constant (HLC) but with a strong dependency on temperature (α-HCH partitions into water about seven times more strongly at 0°C than at 25°C (Kucklick et al. 1991)), low affinity for particles and resistance to degradation in cold water (Ngabe et al. 1993). These physical-chemical properties result in the evaporation of HCH from temperate and tropical regions (Takeoka et al. 1991), dispersion through the atmosphere and deposition into the Arctic. Partitioning of HCHs from air to water is favoured at lower temperatures (Kucklick et al. 1991) with the result that concentrations of HCHs in the Arctic Ocean are typically an order of magnitude or higher than those in tropical waters, although the distribution of HCHs in the Arctic Ocean is far from uniform. Although HCHs are the most abundant organochlorine in the Arctic Ocean, few measurements have been made for β-HCH.

Two significant drops in global technical HCH usage have been identified. In 1983, China banned the use of technical HCH and in 1990 India and the former Soviet Union reduced or banned the use of technical HCH (Li et al. 1998a, Li et al. 1998b). Significant drops in atmospheric α-HCH in the Arctic were observed between 1982 and 1983 and again between 1990 and 1992 (Li et al. 1998a). No temporal data for β-HCH are currently available. Concentrations of HCHs in Arctic waters have a different trend from those in air. The strong partitioning of HCH from air to water means that water phases ultimately become more important reservoirs than the atmosphere, containing over 90% of the inventory. The result of the dramatic decrease in atmospheric HCH concentration is that the surface water in some oceanic regions became undersaturated and therefore started to outgas (Jantunen and Bidleman 1995, Jantunen and Bidleman 1996). In other words, the concentration of α-HCH (and probably β-HCH) in Arctic waters increased until around 1990-1992 and γ-HCH reached an equilibrium stage around 1993. Since contamination of the marine environment by HCH depends mainly on the concentration of HCH in water, concentrations of both α-HCH and β-HCH in Arctic marine biota should show a decrease after 1992. Preliminary analyses of data for ringed seals, polar bears and seabirds indicate that β-HCH increased during the 1980s and may now be decreasing (in ringed seals and seabirds) as predicted (Addison, personal communication; Norstrom, personal communication).

Little is known about β-HCH in the Arctic or how its HLC varies with temperature. β-HCH is present at low levels in Arctic air (Halstall et al. 1998) and sea water (Jantunen and Bidleman unpublished data) but is found in increasing concentrations at higher trophic levels although the percentage of β-HCH in ΣHCH does not increase smoothly with trophic level (Muir et al. 1988).

Activities in 2000-2001

A large data set on HCH isomer concentrations was compiled for Arctic marine biota for interpretation of HCH dynamics and fate in the Arctic. Data for ringed seals and seabird eggs were the most complete and were used for interpretation of trends in biota. Six high volume water samples were collected from the Canadian Arctic Archipelago for analysis of HCH isomers, including β-HCH, and initial data are reported. Initial results for β-HCH HLC are also presented.

Results and Discussion

Review of existing data for HCH isomers

Abiotic

The long-term trend in Arctic air concentrations of α-HCH has been presented by Li et al. (1998a). Two sharp decreases in concentration occurred in 1982-1983 and between 1990-1992. These seem to be responses to the change of global technical HCH usage or α-HCH emissions given that global emissions of α-HCH and mean air concentrations in the Arctic regions from 1979 to early-1990s are strongly correlated. However, after 1990, global emissions and Arctic air concentrations are not correlated. This indicates that since the early-1990s, the concentrations of α-HCH in Arctic air have not responded to the global α-HCH emission trends. In fact, the concentrations of α-HCH in the air and seawater in the Arctic have been in an equilibrium state since the early 1990s. The background air concentration should decrease accordingly after 1996 when α-HCH concentrations in the Arctic seawater decrease gradually.

Since β- and α- HCH are both in technical HCH but not in lindane, β-HCH should behave in many respects like α-HCH. Therefore, the temporal trends of α-HCH discussed above should also be true for β-HCH. If one supposes that β-HCH follows the same route as α-HCH to enter the Arctic air through long-range transport, and assuming the background value decreases linearly to zero from early 1990 back to 1945, an equation may be proposed for the calculation of the air concentration (C) of β-HCH in the Arctic before the beginning of 1990 (Y) (using the concentration data of 0.75 $pg{\cdot}m^{-3}$ in 1993, measured at Alert [Halstall et al. 1998]):

$$C = 0.017(Y-1945) + 4.31E$$

The estimated air concentration of β-HCH in the Arctic would therefore have been in the range of 57 to 72 $pg{\cdot}m^{-3}$ from 1970 to 1980, and in the range of 70 down to 20 $pg{\cdot}m^{-3}$ from 1981 to 1990.

Several research groups have measured air concentrations of both α-HCH and γ-HCH in the Arctic, however data for β-HCH are sparse. If the β-HCH in the source regions can reach the Arctic air via atmospheric long-range transport along with α-HCH, then it should not have been very difficult to measure concentrations of β-HCH in the Arctic air at the beginning 1980s when the air concentration of α-HCH in the Arctic reached the highest values. The fact that there were no reports of β-HCH in Arctic air during the early- to mid-1980s may indicate that atmospheric long-range transport was not able to bring enough β-HCH into the Arctic air to be detected. Therefore, the estimated concentrations of β-HCH in the Arctic air as calculated above may not represent the real situation.

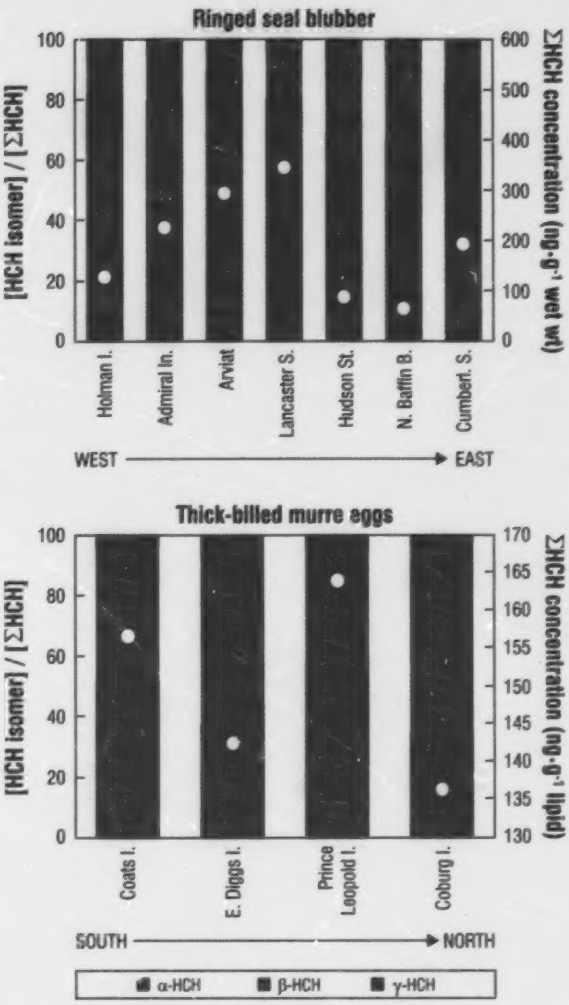
Biota

This study has confirmed that the concentrations and relative proportions of the three HCH isomers vary in Arctic marine biota (e.g. Muir et al. 2000a, Moisey et al. 2001). Variation in HCH isomer patterns has been shown to be related to differences in biotransformation capacity among species (Moisey et al. 2001). Because of this, the use of ΣHCH to assess the temporal and spatial trends of individual HCH isomers may lead to false conclusions and needs to be considered in studies of HCH. The use of different analytical methods was also examined due to concerns about differences between electron capture (ECD) and mass spectrometer (MSD) detectors. Comparison of HCH isomer concentrations in seabird eggs using the same sample extract on ECD and MSD detectors found that these detectors gave similar results supporting the use of HCH data generated by either ECD or MSD.

Spatial and temporal trends of HCH isomers in Arctic marine biota

Examination of the HCH isomers in ringed seal blubber and thick-billed murre eggs shows that concentrations and relative proportions of HCH isomers vary spatially in the Canadian Arctic (Figure 1). Efforts to properly evaluate these trends are limited by the small amount of data. No strong relationship between concentration or relative proportions with latitude or longitude were observed for either species, which suggests that exposure levels and differences in feeding habits are likely important variables. Concentrations in seals collected in the east are lower than those from the west (Figure 1), although this is somewhat confounded by differences in collection year and latitude. The concentration trend is in general

Figure 1. Spatial trends in the relative proportions of HCH isomers (bar graph) and concentration (symbol) in ringed seals collected between 1992 and 1996 and thick-billed murre eggs collected in 1993*



* Note that Coats and East Digges Islands are at similar latitudes.

agreement with ΣHCH concentrations observed in a large set of ringed seal samples covering a wider geographical area (Muir et al. 2000b). The sites that had the lowest ΣHCH concentrations, Hudson Strait and Northern Baffin Bay, also had the lowest proportion of α-HCH (Figure 1). Concentrations and relative proportions of HCH isomers in thick-billed murre eggs showed no trend with latitude (Figure 1). However, the diet and migration pattern vary between these murre colonies (Braune et al. 2001), which may influence and confound geographical trends. The Digges and Coats Islands birds were feeding on higher trophic-level prey. The murres of Prince Leopold and Coburg Islands winter off southwestern Greenland whereas the Digges and Coats Islands murres spend the winters off Newfoundland. Levels of organochlorines are likely higher in the waters off Newfoundland compared with southwestern Greenland. As with the ringed seals, lower ΣHCH concentrations were associated with a lower proportion of α-HCH.

ΣHCH concentrations in ringed seals and thick-billed murres appear to have started to decline as of the late 1990s, after a period of no decline in the 1980s and early 1990s. In both ringed seal blubber and thick-billed murre eggs, there has been a decrease in the relative proportion of α-HCH with time (Figures 2 and 3) due to a decrease in concentration of α-HCH but also because of no change in β-HCH concentrations. The declines in HCH concentrations with time began at a later date than other persistent organic pollutants (POPs) groups, such as PCBs and DDTs, in part because HCH is still widely used around the globe and because the Arctic Ocean is considered a continuing source of these chemicals to the Arctic. This lag in declining concentrations of HCH in biota was predicted by Addison and Smith (1998). The lack of a decline in β-HCH likely reflects the recalcitrant nature of this isomer and its lower HLC as compared with the other HCH isomers, but is likely to decline in the Arctic with continuing decline in HCH use around the globe.

There were no relationships between concentrations of α-HCH (linear regression, $p = 0.43$), γ-HCH ($p = 0.28$) and ΣHCH ($p = 0.85$) and year in ringed seals collected at Holman Island (1981, 1991, 1996). β-HCH was found to be significantly increasing with year in these seals (liner regression, $r^2 = 0.28$, $p < 0.001$). Concentrations of α-HCH (linear regression, $r^2 = 0.27$, $p < 0.001$), γ-HCH ($r^2 = 0.11$, $p < 0.01$) and ΣHCH ($r^2 = 0.24$, $p < 0.001$) were all found to be declining in ringed seals collected in Hudson Strait between 1989 and 1998. No relationship between β-HCH and year ($p = 0.13$) was found in these seals. Combining all data and using ANCOVA with type III sum-of-squares showed that year, sex or age were not significant variables ($p > 0.1$) in α-HCH concentrations in ringed seals, although concentrations varied among stocks ($p < 0.001$). Type III sum-of-squares removes the influence of each variable before analysis of the significance of the variable of interest. ANCOVA analysis found that stock, year and sex were significant variables in β- and γ-HCH concentrations but age was not. Stock was the only significant variable describing ΣHCH concentrations in the ringed seals as one group. Muir and Norstrom (2000) concluded that there has been no change in ΣHCH concentrations between the mid-1980s to the 1990s in ringed seal blubber from three locations in the eastern

Figure 2. Temporal trends of the relative proportion of α-HCH in ringed seals collected from Holman Island (1981, 1991, 1996) and Hudson Strait (1989, 1990, 1994, 1998)

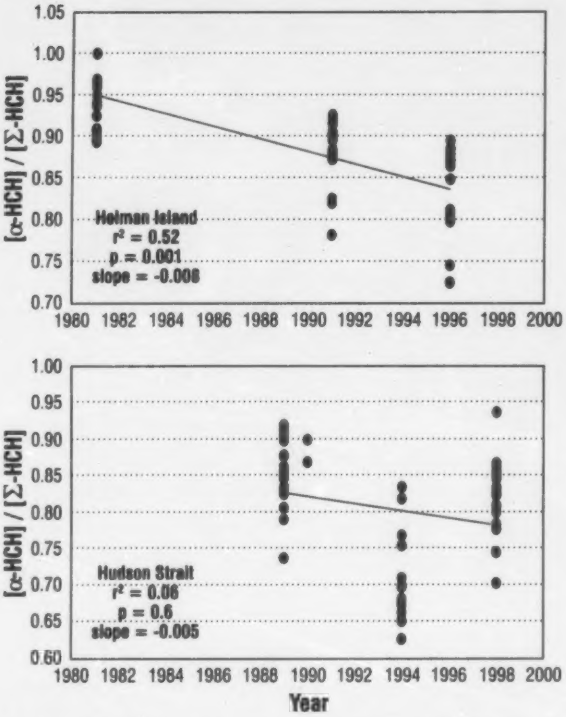
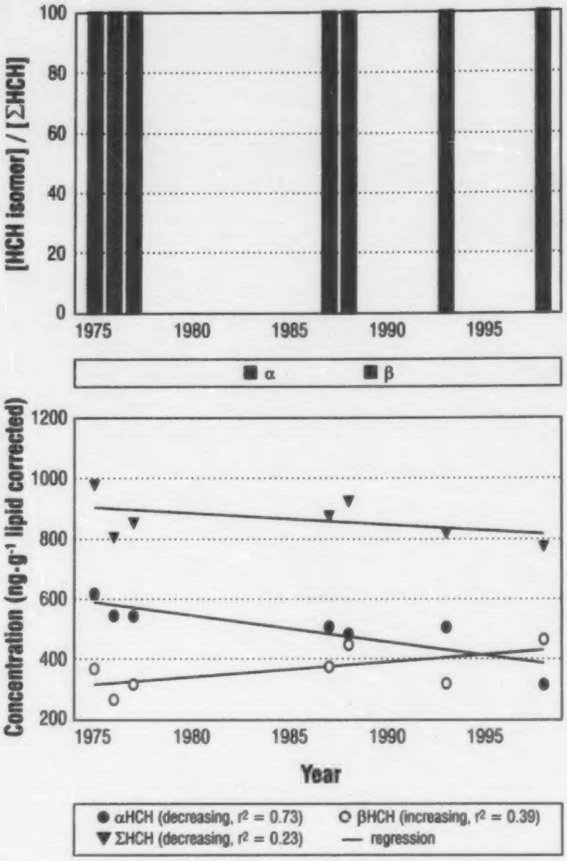


Figure 3. Temporal trends in relative proportions and concentrations in thick-billed murre eggs collected on Prince Leopold Island



Canadian Arctic. Addison and Smith (1998) concluded that ΣHCH concentrations did not change in the Holman Island ringed seals from the 1980s until the 1990s. Concentrations of α-HCH and γ-HCH are significantly declining, while β-HCH is increasing, in thick-billed murre eggs collected at Prince Leopold Island (Figure 3). This has resulted in a decease in the relative proportions of α-HCH in these eggs. Similar trends in HCH isomers have been observed in northern fulmars and black-legged kittiwakes (Braune et al. 2001).

New measurements of HCH isomers in Arctic marine waters

HCH isomers were determined in water samples collected in the eastern Archipelago on the Swedish Tundra Northwest-99 expedition in July 1999. Two types of samples were collected: high-volume (100 L) and low-volume (4 L). The low-volume samples were analyzed for only α- and γ-HCHs and enantiomers of α-HCH; β-HCH was determined in the high-volume samples. Results are given in Table 1. Our concentrations are higher than those found by Strachan (personal communication) on the same expedition: 1.01 ng·L⁻¹ α-HCH and 0.19 ng·L⁻¹ γ-HCH for the Hudson Strait, Foxe Basin and Gulf of Boothia. Our single sample in Barrow Strait contained 3.5 ng·L⁻¹ α-HCH, which compares well with 2.7 to 3.7 ng·L⁻¹ found by Macdonald et al. (1999) at three stations in Barrow Strait on the Joint Ocean Ice Studies 1997 cruise. The α-HCH in all water samples was non-racemic (enantiomer ratio (ER) = 0.79 to 0.85). Concentrations of β-HCH in the eastern Archipelago ranged from 0.04 to 0.09 ng·L⁻¹ and averaged 0.067 ng·L⁻¹. Strachan (personal communication) found 0.14 ng·L⁻¹ for the region. Ratios of α-HCH/β-HCH ranged from 32 to 64.

Determination of HLC for β-HCH

Henry's law constant [HLC, Pa·(mol·m⁻³)⁻¹] is a critical parameter for estimating precipitation scavenging of HCHs and other POPs from the atmosphere and gas exchange across lake and ocean surfaces. The HLC for β-HCH was experimentally measured using the bubble stripping (BS) (Kucklick et al. 1991, Jantunen and Bidleman 2000) and dynamic headspace (DH) (Yin and

Table 1. Concentration ($ng \cdot L^{-1}$, mean ± SD) of HCH isomers and ERs[1] of α-HCH in TNW-99[2] water samples from the eastern Archipelago of the Canadian Arctic

		Low-volume (4L) samples				High-volume (100L) samples
Location	**n**	**α-HCH**	**γ-HCH**	**ER of α-HCH**	**n**	**β-HCH**
Davis Strait	8	1.5 ± 0.6	0.24 ± 0.09	0.85 ± 0.034		
Hudson Strait	9	2.9 ± 1.1	0.26 ± 0.07	0.84 ± 0.022	2	0.045 ± 0.007
Foxe Channel	4	2.3 ± 0.4	0.21 ± 0.03	0.83 ± 0.018	2	0.059 ± 0.002
Foxe Basin	4	2.7 ± 0.5	0.21 ± 0.01	0.79 ± 0.027	1	0.073
Gulf of Boothia	5	2.9 ± 0.7	0.31 ± 0.06	0.81 ± 0.017	1	0.091
Prince Regent Inlet	2	2.7 ± 0.1	0.27 ± 0.08	0.80 ± 0.010		
Barrow Strait	1	3.5	0.41	0.79		

[1] Enantiomer ratios

[2] Swedish Tundra Northwest-99 expedition

Hassett 1986) methods. In the BS method, nitrogen is bubbled through a column of water to strip dissolved HCHs and the HLC is calculated from the concentration decrease with time. In the DH method, dissolved HCHs are stripped by bubbling with nitrogen and the volatilized HCHs are trapped on a sorbent cartridge. The partial pressure of the chemical is calculated from the quantity of HCHs trapped on the cartridge and the air volume, using the ideal gas law. The HLC is the partial pressure divided by the concentration in water. The DH technique is especially useful when the HLC is low and the chemical strips very slowly, as is the case for β-HCH at the colder temperatures.

The HLCs for α-, β- and γ-HCHs were determined at 5, 20, 30 and 35°C in deionized water. Agreement between the DH and BS methods averaged 15% for α- and γ-HCH at 20 and 5°C and for β-HCH at 20°C. Only the DH method was used for β-HCH at 5°C because of slow stripping. The temperature dependence of the HLC was expressed as the slope and intercept of Clausius-Clapeyron plots:

$$\text{Log HLC} = m/T + b$$

where the water temperature (T) ranged from 273 to 308 K. Regression parameters and HLC values at 298 K are given in Table 2. HLCs for α- and γ-HCHs determined here are similar with those recently reported by Jantunen and Bidleman (2000), and are about 25% lower than results obtained by Kucklick et al. (1991). The α-HCH HLC reported by Altschuh et al. (1999) is about twice our values, but the β-HCH HLC values are similar.

Emission inventories

Based on previous work on technical HCH and α-HCH (Li 1999a, 1999b, Li et al. 2000), global gridded β-HCH usage inventories with 1° latitude by 1° longitude resolution have been created. The usage data, the annual emission factors, and the application modes have been localized on

Table 2. Temperature dependence of HLC[1] for HCH isomers

				HLC at 298 K			
Compound	**m[2]**	**b[3]**	**r^2**	**This work**	**Ref. 1[4]**	**Ref. 2[5]**	**Ref. 3[6]**
α-HCH	-3377	11.108	0.91	0.60	0.76	0.65	1.24
β-HCH	-3609	10.669	0.86	0.036			0.045
γ-HCH	-3254	10.272	0.89	0.23	0.35	0.27	

[1] Henry's law constant

[2] Slope

[3] Intercept

[4] Source: Kucklick et al. 1991

[5] Source: Jantunen and Bidleman 2000

[6] Source: Altschuh et al. 1999

a 1° by 1° latitude and longitude grid system, and combined to estimate β-HCH emissions to the atmosphere. The total technical HCH usage was estimated to be around 10 million t between 1948 and 2000 (Li 1999a). Assuming that technical HCH contains 9% β-HCH, around 900 kt of β-HCH has been used, and 390 kt has emitted to the atmosphere during the same period of time.

Conclusions

This project has shown that the spatial and temporal trends of concentrations and relative proportions vary among HCH isomers, among species and among populations of seabirds and marine mammals. Future work on HCH should consider all isomers and not just ΣHCH. The results also support the continued monitoring of organochlorine contaminants in a number of species and at a number of locations. β-HCH concentrations are much lower than α- and γ-HCH in Canadian Arctic waters. The low water concentrations support conclusions that higher levels of β-HCH in organisms are due to the recalcitrant nature of this isomer. The HLC of β-HCH is an order of magnitude less than α- and γ-HCH. This lower HLC suggests that migration of β-HCH to the Arctic and outgasing from Arctic Ocean waters will be slower than the other HCH isomers. This will likely result in delays in the decline of β-HCH in the Arctic environment, and advocates more attention to this isomer in future studies in the Arctic. Future work will focus on examining trends in abiotic matrices based on data generated in the past year and comparing abiotic trends with biotic trends.

Expected Project Completion Date

March 31, 2002

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Retrospective Survey of Organochlorines and Mercury in Arctic Seabird Eggs

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Abstract

We have previously measured the levels of organochlorines and mercury in archived Arctic seabird eggs and confirmed that the concentrations of most organochlorine compounds have been decreasing and that mercury concentrations have been increasing in Arctic seabirds. To evaluate whether temporal trends of organochlorines vary between species we compared the temporal trends of organochlorines among seabird and marine mammal species. Although somewhat limited by sample sizes and access to temporal trend data sets, our analysis has shown that the rate of change of organochlorine contaminant concentrations in Arctic seabirds and marine mammals varies among species. These results support the continued monitoring of organohalogens in a suite of Arctic species. A number of halogenated organic contaminants, which have never been measured in Canadian Arctic seabirds, were also quantified. Preliminary results from seabird livers sampled from 1975 and 1993 showed that concentrations of most dioxins and furans decreased in northern fulmars and black-legged kittiwakes but increased in thick-billed murres. Levels of polybrominated diphenyl ethers have increased in all three species and concentrations of non-*ortho* PCBs have increased in northern fulmars. Levels of some dioxins, furans, non-*ortho* PCBs and polybrominated diphenyl ethers in seabirds are higher than levels found in marine mammals. Toxaphene, halogenated dimethyl bipyrroles, chlorinated terphenyls, hexabromo biphenyls and TCP-methane were also detected in seabirds, but concentrations were low.

Key Project Messages

1. Temporal trends of organochlorine (OC) concentrations vary between Arctic seabird and marine mammal species suggesting that a suite of species is needed in order to assess these chemicals in the Arctic.
2. A number of halogenated organic contaminants, which had not previously been reported for Canadian Arctic seabirds, were measured. Among these, levels of dioxins, furans, non-*ortho* PCB congeners and polybrominated diphenyl ethers were considered significant and require additional analysis and evaluation in seabirds.

Objectives

To address the question of the utility of Arctic seabird eggs as an indicator of contaminant temporal trends under the Northern Contaminants Program "Monitoring" Blueprint (NCP 2000), it was proposed that:

1. Archived Arctic seabird egg contents be re-analyzed for OCs according to a standardized pooling and analytical protocol in order to confirm whether those residues have been decreasing since the mid-1970s.
2. The mercury (Hg) and selenium (Se) data for Arctic seabird eggs be analyzed to determine whether or not those levels have been increasing or decreasing since the mid-1970s
3. Egg contents and adult livers be analyzed by full scan and inductively coupled plasma mass spectrometry to identify any "new" or previously unidentified OCs (MS full scan) or metals (ICP) which may have entered the Canadian Arctic food chain.

Introduction

Eggs of seabirds have been used to monitor contamination of the Canadian Arctic marine environment since 1975 (Noble and Elliott 1986, Nettleship and Peakall 1987, Noble 1990, Muir et al. 1999). At the time of egg formation, OC compounds are transferred along with fat to the eggs (Mineau et al. 1984) thus reflecting the contaminant burden in the female at the time of laying (Braune and Norstrom 1989). Both Hg (Fimreite 1979, Lewis and Furness 1993) and Se (Heinz 1996) are also transferred to the eggs. Contaminant burden is comprised of residues assimilated over a long time period and, particularly in migratory species, may represent exposure from a number of different locations (Hebert 1998, Monteiro et al. 1999).

Biomagnification of many chemical residues has been shown to result in higher concentrations of many compounds with increasing trophic level (Riisgard and Hansen 1990, Jarman et al. 1996, Kidd et al. 1998). Therefore, interpretation of contaminant concentrations in seabirds may be confounded if seabird populations shift their dietary patterns over trophic levels through time. Fortunately, retrospective analysis of trophic level in seabirds is possible through the measurement of naturally occurring stable isotopes of nitrogen ($\delta^{15}N$), and to a lesser extent, carbon ($\delta^{13}C$) (Hobson and Welch 1992, Hobson et al. 1994, Hebert et al. 1999). This is also true of seabird eggs since stable isotope ratios in egg material are expected to reflect the diet of the female prior to or during laying (Hobson 1995, Hebert et al. 1999).

Few long-term data sets exist to give a clear picture of how concentrations of contaminants have changed over time at northern latitudes. In the Canadian Arctic, previous contaminant trend information is available for seabird eggs collected on Prince Leopold Island in Lancaster Sound, Nunavut. Contaminants data from samples collected in the mid-1970s (Nettleship and Peakall 1987) have been compared with data from eggs collected in the late 1980s (Noble 1990) and early 1990s (Muir et al. 1999), all of which suggested that levels of many OCs were declining. Those samples were, however, analyzed at different times using different analytical techniques. As well, time trends for metal concentrations are nonexistent because concentrations of trace metals were never measured in those samples.

In this study, we provide new insight into contaminant trends in seabirds from the high Arctic by reanalyzing archived samples using standardized laboratory protocols and by extending the trend analyses of eggs from earlier studies. These data have already been presented (Braune 1999, Braune 2000).

Activities in 2000-2001

Species comparison of temporal trends in POPs

Analysis of covariance (ANCOVA) was used to assess and compare OC temporal trend data for seabirds, ringed seals and polar bears using the model:

$$OC = \mu + species + year + species * year + \varepsilon$$

where OC is the lipid corrected concentration of hexachlorobenzene (HCB), ΣHCH, *p,p'*-DDE, Σchlordane and ΣPCB. The significance of each variable was then assessed with Type III Sum of squares test. Efforts to test differences in slopes among species were limited by sample size. The OCs were chosen because there was sufficient data for each species and these chemicals represent a good range of the physical chemical properties encountered in POPs measured in the Arctic.

Newly identified organohalogen compounds and metals in seabirds

Liver samples of all three seabird species from 1975 and 1993 as well as egg samples from 1993 were analyzed at the National Wildlife Research Centre (NWRC) laboratories for dioxins (PCDDs), furans (PCDFs) and non-*ortho* PCBs (NOPCBs) using GC/MS Selected Ion Monitoring (SIM). GC/MS Total Ion Chromatography (TIC) was used to confirm the presence and to estimate the levels of toxaphene, polybrominated diphenyl ethers (PBDEs), polychlorinated diphenyl ethers (PCDEs), halogenated dimethyl bipyrroles (HDBPs), hexabromo biphenyls, TCP-methane, TCP-methanol and chlorinated naphthalenes using GC/MS TIC. Egg samples from 1993 as well as the liver samples were also analyzed for multiple elements using Elan ICP-MS.

Results

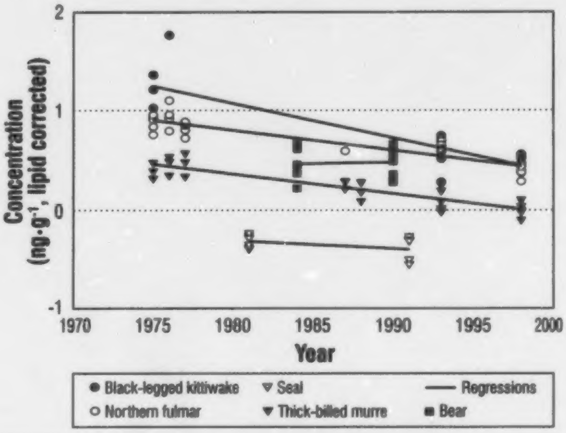
Species comparison of temporal trends in POPs

Results of the ANCOVA showed that concentrations of HCB, ΣHCH and ΣPCB were significantly different among species, had significant temporal trends, and rates of these temporal trends varied between species (all p values < 0.05). Including data for all species, HCB is significantly declining with time and at a greater rate than ΣHCH, ΣPCBs and DDE. The greatest rate of decline was observed in the ringed seals, although not statistically different than black-legged kittiwakes, thick billed murre or polar bears; the rate of decline in northern fulmars was significantly slower. ΣHCH concentrations were actually found to be increasing, although marginally, in these seabirds and marine mammals. Again, only northern fulmars had a statistically different temporal trend. ΣPCB concentrations in all species were significantly declining with time (Figure 1). Black-legged kittiwakes had the greatest rate of decline, which is statistically different than the other species ($p < 0.05$). DDE is significantly declining in all species ($p < 0.05$) but no differences were observed between species ($p = 0.06$) or in the rate of decline among species ($p = 0.08$). ΣCHLOR is significantly declining in all species ($p < 0.05$) but no differences were observed between species ($p = 0.31$) or in the rate of decline among species ($p = 0.32$).

Newly identified organohalogens and metals in seabirds

PCDDs, PCDFs and non-*ortho* PCBs were found in all the Arctic seabird samples analyzed for this project. In the kittiwake liver samples, concentrations of total PCDDs, PCDFs and non-*ortho* PCBs decreased from 1975 to 1993 (Table 1). In fulmar liver samples, concentrations of total PCDDs and PCDFs decreased and non-*ortho* PCBs increased from 1975 to 1993, and in murre liver samples, concentrations of total PCDDs and PCDFs increased and non-*ortho* PCBs decreased from 1975 to 1993 (Table 1). PCB-126 was the predominant non-*ortho* PCB congener in all years and all Arctic seabird samples recently analyzed by NWRC. The NOPCB fraction of the TEQ decreased and the PCDF fraction increased from 1975 to 1993 in kittiwake and murre livers. In fulmars, the PCDFs constituted the dominant fraction in both 1975 and 1993 livers. Calculated TEQ values were highest in northern fulmars both in 1975 and 1993 (Table 1).

Figure 1. Temporal trends of ΣPCB in arctic seabirds, ringed seals and polar bears



Toxaphene was detected in every seabird sample except for the pool of kittiwake livers from 1975. The highest estimated level of toxaphene was found in the pool of kittiwake eggs from 1993 (64 ng·g^{-1} wet wt) and the second highest level was found in the 1993 pool of fulmar eggs (53 ng·g^{-1} wet wt). Total PBDE was present at low ng·g^{-1} levels in most of the samples analyzed. The highest estimated PBDE levels (3 ng·g^{-1} wet wt; or about 60-70 ng·g^{-1} lipid wt) were detected in the 1993 egg and liver samples of kittiwakes. The 1993 murre samples and the 1993 fulmar samples also contained ng·g^{-1} levels. Only a trace of PBDE-47 was detected in the pool of kittiwake livers from 1975 and no PBDEs were detected in the liver samples of the other two species from 1975. PBDE-47 was the major PBDE in all the samples. Halogenated dimethyl bipyrroles were detected in all of the 1993 samples and only one of the liver samples from 1975. The major contaminant found was $C_{10}H_6N_2Br_4Cl_2$ followed by $C_{10}H_6N_2Br_6$. The highest estimated level (a total of 5 ng·g^{-1} wet wt) was found in the kittiwake egg sample from 1993. Trace amounts (< 2 ng·g^{-1} wet wt) of chlorinated terphenyls, hexabromo biphenyls and TCP-methane were detected in most of the Arctic seabird samples. No chlorinated diphenyl ethers, TCP-methanol or chlorinated naphthalenes were detected in any of these samples (detection limit ~ 2 ng·g^{-1} wet wt).

Results for aluminum, antimony, barium, beryllium, boron, cobalt, lead, nickel, silver, thallium, uranium and vanadium were all below the detection limit. Detectable amounts of strontium, mercury, arsenic, cadmium, chromium, copper, iron, manganese, molybdenum, selenium, tin and zinc were found in some of the samples analyzed but the data have not yet been interpreted.

Table 1. Dioxin, furan and non-ortho PCB concentrations ($pg \cdot g^{-1}$ or ppt wet weight) in seabirds from the Canadian Arctic

Species					
Tissue	**Year**	**ΣPCDDs**	**ΣPCDFs**	**ΣNOPCBs**	**ΣTEQ[1]**
Kittiwake					
Liver	1975	35	44	136	214
Liver	1993	5	21	21	48
Egg	1993	7	35	37	78
Fulmar					
Liver	1975	69	609	10	689
Liver	1993	27	271	59	357
Egg	1993	10	40	33	83
Murre					
Liver	1975	1.5	3.3	161	166
Liver	1993	2.9	9.7	11	24
Egg	1993	2.4	8.1	15	26

[1] TEQ values calculated using World Health Organization avian TEFs for PCDDs, PCDFs and non-ortho PCBs as given in Van den Berg et al. 1998.

Discussion and Conclusions

Species comparison of temporal trends in POPs

Although somewhat limited by small sample size, statistical analysis of the temporal trends of OCs in Arctic seabirds, ringed seals and polar bears suggest that trends are significantly different among species. Efforts to draw more statistically powerful comparisons of temporal trends between species found differences at the p value of 0.05 but the statistical method, using ANCOVA model with a Bonferroni multiple correction, required $p < 0.005$ to be significant. Despite this, the ANCOVA method provides concrete evidence that the rates of decline of most OCs vary among species. Therefore, future monitoring of OCs in Arctic biota should consider a suite of species that represent relevant groups of animals in the Arctic.

Newly identified organohalogens and metals in seabirds

Concentrations of HxCDDs, PnCDFs and HxCDFs, in particular, found in Arctic seabird livers exceed levels reported for marine mammals in the Canadian Arctic (de March et al. 1998) by several orders of magnitude. Ringed seals, polar bears and walrus in the the Canadian Arctic tend to contain relatively high TCDD and low PnCDD and PnCDF levels (de March et al. 1998) whereas Arctic seabirds show the opposite pattern. Concentrations of PCDD/F homologs in the Arctic seabirds are in the range reported for seabirds from temperate North America and Europe (Hebert et al. 1994, Van den Berg et al. 1987).

PCBs with 2,3,7,8-TCDD-like activity have been shown to adversely affect patterns of survival, reproduction, growth and metabolism with PCB-126 being among the most toxic of all PCB congeners to birds (Eisler and Belisle 1996). Elliott et al. (1996) have suggested a no observed effect level (NOEL) of 100 $ng \cdot kg^{-1}$ and a lowest observed effect level (LOEL) of 210 $ng \cdot kg^{-1}$ TEQ on a whole egg (wet weight basis) for bald eagle chicks, and Bosveld et al. (2000) have estimated the LOEL for induction of CYP1A in the common tern as approximately 25 $ng \cdot g^{-1}$ TEQ liver lipid. Wu et al. (2000) have calculated TEQs based on PCDD/Fs in livers and eggs of piscivorous birds from a heavily polluted lake area in China to be 552 $pg \cdot g^{-1}$ and 107 $pg \cdot g^{-1}$, respectively. The TEQs for livers and eggs of Canadian Arctic fulmars (Table 1) are certainly within the range of the Chinese samples, and the liver TEQs (lipid conversion: 1975: 27 $ng \cdot g^{-1}$ lipid wt.; 1993: 8.2 $ng \cdot g^{-1}$ lipid wt.) exceeded the LOEL TEQ for induction of CYP1A in common terns in the 1975 samples.

Although laboratory studies have shown considerable variation in species sensitivity, developing embryos are consistently more sensitive than adult birds to TCDD-like chemicals (Peterson et al. 1993). Coplanar PCBs have the potential to contribute more to total dioxin-like toxic activity in biota than chlorinated dioxins and dibenzofurans, and therefore monitoring for PCDDs and PCDFs is ill advised without comparable data for coplanar PCBs (Metcalfe and Haffner 1994). Given that there is evidence to suggest that: (i) the TEQs for the Canadian Arctic fulmars may be nearing levels of concern, (ii) levels of some PCDD/Fs in Arctic seabirds exceed levels found in marine mammals by several orders of magnitude, and

(iii) levels of PCDD/Fs in thick-billed murres may be increasing – it is proposed that a detailed retrospective analysis be undertaken to examine temporal trends of PCDDs, PCDFs and coplanar PCBs in Canadian Arctic seabirds.

Although the data suggest that exposure to toxaphene has increased from 1975 to 1993, the highest level reported (64 $ng \cdot g^{-1}$ wet wt) is still an order of magnitude lower than levels reported for black duck eggs where reproduction was normal, and one to two orders of magnitude lower than levels reported for marine mammals from the Canadian Arctic (Muir et al. 1999). Therefore, monitoring of toxaphene in Canadian Arctic seabirds is probably not warranted at this time. Halogenated dimethyl bipyrroles, which are naturally occurring, mixed bromine/chlorine, persistent organic compounds, have been shown to bioaccumulate in seabird eggs (Tittlemier et al. 1999). Given that these are naturally occurring marine compounds, no further monitoring of these compounds in Canadian Arctic seabird eggs is planned at this time.

Although the data suggest that exposure to PBDEs has increased from 1975 to 1993, the highest level reported is an order of magnitude lower than levels reported for Swedish black guillemots (Sellström et al. 1993), but is still higher than levels reported for Canadian marine mammals (Addison 2000, Stern and Ikonomou 2000). Given that evidence from several sources suggests that PBDEs seem to be increasing in the Canadian Arctic and elsewhere, it is proposed that a detailed retrospective analysis be undertaken to examine temporal trends of PBDEs in Canadian Arctic seabirds.

Expected Project Completion Date

This is part of an ongoing monitoring program. The next sampling period will be in 2003.

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Role of Contaminants in Seaduck Population Decline: Metals in Oldsquaw

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Abstract

Western populations of oldsquaw are in decline and although populations appear stable in the east, oldsquaw are considered to be a *Species of Continental Conservation Concern*. Analyses of mercury, selenium and copper in liver, cadmium in kidney, and lead in bone suggest that the males generally contained higher residue levels than the females, except for lead in bone of the western birds. Both cadmium in kidney and selenium in liver were considerably higher in western birds compared with eastern birds. Only selenium in livers of some of the western birds exceeded toxicological threshold values found in the literature. It is not known whether or not the birds are more exposed to metal contamination on the Arctic breeding grounds or on their overwintering grounds. Measurements of naturally occurring stable isotopes in foodwebs will be used to discriminate birds that wintered in marine areas from those that wintered in freshwater environments, such as the Great Lakes. Analysis of metal residue data in combination with stable isotope data will then be used to determine if birds overwintering on the Great Lakes risk greater exposure to contaminants than those overwintering in marine environments.

Key Project Messages

1. Male oldsquaw generally contained higher metal residue levels than the females except for lead (Pb) in bone of the western birds.
2. Only selenium (Se) in livers of some of the western birds exceeded toxicological threshold values found in the literature.

Objectives

To determine the role of metals in declining populations of oldsquaw through the following:

1. Archived samples of oldsquaw collected from their Canadian Arctic breeding grounds will be analyzed for mercury (Hg), Se and copper (Cu) – in liver, cadmium (Cd) – in kidney, Pb – in wing bone, and selected samples be screened for a wider range of metals – in liver).
2. Archived samples of oldsquaw wing bone will be analyzed for stable isotopes ($^{13}C/^{12}C$; $^{15}N/^{14}N$ and $^{34}S/^{32}S$) and strontium (Sr) to discriminate whether birds from certain geographical areas of the Arctic

are overwintering in freshwater (i.e. Great Lakes) or marine environments.

Introduction

North American populations of oldsquaw (*Clangula hyemalis*) are declining in the west, but are apparently stable in the east (Canadian Wildlife Service et al. 1997). Nevertheless, oldsquaw are considered to be a *Species of Continental Conservation Concern*. This species nests in greater numbers in the high Arctic than any other duck (Bellrose 1980). Oldsquaw nesting in the eastern Canadian Arctic likely winter along the Atlantic coast whereas western Arctic birds winter in the Bering Sea and along the Pacific coast of Alaska and British Columbia (Bellrose 1980). Considerable numbers also winter on the Great Lakes. It is unknown where the dividing line occurs between the two breeding populations.

Oldsquaw are harvested by Aboriginal people and sport hunters alike, but numbers taken are unlikely to be the cause of the decline (Canadian Wildlife Service et al. 1997). Heavy metal contamination from benthic organisms they eat may be an important threat to oldsquaw. As well, high Pb levels, resulting from spent shot ingested on the breeding grounds, are suspected of impairing reproductive success of oldsquaw nesting in the Alaskan Y-K Delta (Flint et al. 1997).

Measurements of naturally occurring stable isotopes in foodwebs can be used to delineate relative inputs from freshwater and marine biomes (reviewed by Hobson et al. 1997). This is based on the fact that stable isotopes of carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$), sulfur ($\delta^{34}S$) and hydrogen (δD) are typically enriched in marine systems, as compared to terrestrial or freshwater systems, and these isotopic signatures are passed on to consumers. Upon arrival on the breeding grounds, metabolically active tissues of birds that wintered in freshwater environments can be distinguished isotopically from those that wintered in marine areas. Stable isotope values in bird tissues are in dynamic equilibrium with local foodwebs and so it is necessary to choose a tissue with a slow turnover rate to delineate between freshwater and marine wintering ducks. Bone collagen was chosen because it has a turnover rate slow enough for isotope measurements to represent lifetime average values (Hobson and Sealy 1991). This information will be used to determine if birds overwintering on the Great Lakes risk greater exposure to contaminants than those overwintering in marine environments.

Metal residue data for breast muscle from oldsquaw collected from across the Canadian Arctic during 1991 to 1994 suggest that western Arctic populations generally have higher levels of Cd and Se than eastern populations (Braune et al. 1999). It is not known whether or not the birds are more exposed to metal contamination on the Arctic breeding grounds or on their overwintering grounds. The stable isotope measurements should discriminate those birds which overwinter on the Great Lakes, a known contaminated area. As well, Sr measurements should help to corroborate stable isotope findings since Sr levels are known to be higher in marine than freshwater systems. It should then be possible to determine if those birds overwintering on the Great Lakes also contain higher tissue residue levels than the others. The connection between risk of exposure and overwintering area can then be investigated, if such a link exists. Alternatively, if no association between metal levels and overwintering area can be established, the source of contamination may, in fact, be in the Arctic.

Activities in 2000-2001

This study made use of the tissues of 101 adult oldsquaw from the Canadian Arctic archived in the CWS Specimen Bank: 59 birds from the eastern Arctic (east of 95°W) and 42 birds from the western Arctic. Liver, kidney and bone samples were retrieved from the Specimen Bank for each of the 101 birds and analyzed for Hg, Se and Cu in liver, Cd in kidney, and Pb in bone.

Results

Liver, kidney and bone samples were retrieved from the Specimen Bank for each of the 101 birds and analyzed for Hg, Se and Cu in liver, Cd in kidney and Pb in bone (Table 1). Males generally contained higher residue concentrations than females, except for Pb in bone of the western birds. Both Cd in kidney and Se in liver were considerably higher in western birds compared with eastern birds.

Discussion and Conclusions

Based on a review of the literature, Outridge et al. (1999) suggest that > 10 $mg{\cdot}kg^{-1}$ dry wt of Se in the liver of adult female water birds may be associated with reduced adult weight gain, increased teratogenesis and reduced hatchling success. Western female oldsquaw averaged 18.5 $mg{\cdot}kg^{-1}$ dry wt in their livers with values ranging as high as 40 $mg{\cdot}kg^{-1}$. Pain (1996) suggests that > 20 $mg{\cdot}kg^{-1}$ dry wt of Pb in bone is indicative of excessive exposure. The Pb levels found in the oldsquaw are much lower than this. Thompson (1996) suggests that 20 to 30 $mg{\cdot}kg^{-1}$ wet wt (about 60 to 90 $mg{\cdot}kg^{-1}$ dry wt) of Hg in liver and kidney of non-marine birds could cause toxic effects, and Furness (1996) suggests that about 100 $mg{\cdot}kg^{-1}$ wet

Table 1. Mean metal concentrations ($mg \cdot kg^{-1}$ dry wt) in adult oldsquaw from northern Canada

	n[1]	Kidney Cd	Bone Pb	Liver Hg	Liver Cu	Liver Se
EAST						
Female	20-25	34.8	2.8	1.7	18.8	9.2
Male	29-34	56.8	3.7	3.1	32.1	11.1
WEST						
Female	13-14	45.2	3.0	2.0	21.2	18.5
Male	27-28	60.0	1.9	2.4	32.7	21.6

[1] Number of samples analyzed varied depending on availability of tissues.

wt (about 300 $mg \cdot kg^{-1}$ dry wt) in kidney should be considered a tentative threshold level for Cd poisoning in birds. Levels in oldsquaw are well below these threshold levels. Copper and its compounds are not carcinogenic, mutagenic or teratogenic at environmentally realistic concentrations (Eisler 1997). No data are available on Cu toxicity to avian wildlife, but livers of some water bird species have been shown to contain more than 2000 $mg \cdot kg^{-1}$ dry wt of Cu (Eisler 1997). Again, our data for oldsquaw are well below those levels.

Bone samples from those same 101 birds have been analyzed for stable isotope and Sr to discriminate between those individuals wintering in freshwater versus marine environments. Livers of 10 birds with elevated levels of metals have also been analyzed by inductively coupled plasma - mass spectrometry to screen for levels of other metals. The results are in hand but those data have not yet been interpreted.

Expected Project Completion Date

March 31, 2002

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Heavy Metal and Radionuclide Contaminants in Caribou

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Abstract

As part of a continuing program to monitor contaminants in caribou in the Northwest Territories, the livers and kidneys from 20 caribou from the Beverly herd were analyzed for metals and radionuclides. The levels of all metals and radionuclides were similar to results of previous studies on the Beverly herd and were within the range usually found in barren-ground caribou in the Northwest Territories, Yukon and Nunavut. Several metals, including beryllium, arsenic, chromium, and nickel were generally below detection limits in most animals. Average cadmium levels in kidney were 45.6 $mg \cdot kg^{-1}$ dry weight (dry wt), or about 10 $mg \cdot kg^{-1}$ wet wt, which is at the upper end of the range of values reported for barren ground caribou. A value of 209 $mg \cdot kg^{-1}$ dry wt was reported in the kidney of one animal. Total mercury was detected in all samples except for one liver sample, and ranged from 4.4 to 11 $mg \cdot kg^{-1}$ dry wt in the 20 livers analyzed. ^{137}Cs, a remnant of the atmospheric nuclear weapons testing programs of the 1950s and 1960s, was more than twice as high in the kidney (247 $Bq \cdot kg^{-1}$ wet wt) than liver (97 $Bq \cdot kg^{-1}$). ^{137}Cs concentrations are well below the levels expected to cause effects in the animals. The major natural radionuclide is ^{210}Po, which had a mean concentration of 346 $Bq \cdot kg^{-1}$ in liver, similar to the levels found in previous studies with the Beverly herd.

Key Project Messages

1. The livers and kidneys of a subset of 20 female caribou from the Beverly herd were analyzed for metals and radionuclides. They were harvested at Nonacho Lake (61° 59′ N, 109° 28′ W) in the Northwest Territories (NWT).
2. The concentration of cadmium (Cd) and mercury (Hg), two contaminants of concern in the North, were in the upper range of values for barren-ground caribou from the NWT, Yukon and Nunavut. A high Cd level was reported in one kidney sample.
3. Several elements, such as beryllium, antimony, chromium, and silver were below or close to detection limits in most samples.

4. The levels of radionuclides were similar to findings of previous studies of the Beverly herd. ^{210}Po, a natural radionuclide, had a mean concentration of 346 Bq·kg^{-1} wet wt in liver. ^{137}Cs, left over from atmospheric weapons tests in the 1960's, was higher in kidney than liver, but not considered to be of concern for the health of the animal.

Objectives

1. To determine tissue residue levels of metals and radionuclides in caribou given its importance as a country food species.
2. To monitor contaminant exposure in caribou as a representative species of the terrestrial Arctic ecosystem.
3. To provide information on temporal trends in radionuclide and metal levels in several caribou herds to determine whether levels are increasing, decreasing or remaining the same over time.
4. To determine the efficacy of international controls in reducing or eliminating pollutants entering the Canadian Arctic terrestrial ecosystem.

Introduction

Barren-ground caribou (*Rangifer tarandus groenlandicus*) are found across northern Canada, and are a major component of the traditional diet in communities across the NWT, the Yukon and Nunavut. Caribou are strict herbivores that have a winter diet consisting primarily of lichen, which accumulate contaminants more readily than vascular plants because of their large surface area, longevity and ability to bind heavy metals. Because of their diet, long-lived ungulates such a caribou can accumulate significant levels of some metals such as Cd (Froslie et al. 1984, Scanlon et al. 1986), which has implications for both caribou health and human consumption. Caribou are a primary source of food for people and wolves, and their level of contamination is therefore of concern (Muir et al. 1999).

Until recently, information on heavy metal, radionuclide and organochlorine contaminants in caribou and other terrestrial herbivores in Canadian Arctic and sub-Arctic regions was extremely limited, and data on temporal trends were nonexistent (Muir et al. 1999, Thomas et al. 1992). During the 1990s, tissue levels and spatial trends of persistent organic pollutants, heavy metal and radionuclide contaminants were assessed in 10 major barren-ground caribou herds across the NWT (Elkin and Bethke 1995). A wide range of contaminants were detected and provided a good baseline to assess current exposure and changes in residue levels over time. This work indicated levels of some metals and radionuclides were elevated, and led to follow-up work to confirm the levels and potential effects of Cd and ^{210}Po in caribou from south Baffin Island.

This study is part of a larger program to monitor contaminant levels in selected sentinel caribou herds at 5-year intervals. The importance of caribou as a major country food species makes the monitoring of ongoing baseline residue data particularly important. In addition, the defined ranges of caribou herds across the Canadian North and the simple lichen-caribou food chain make caribou a good species to monitor spatial patterns and temporal trends of contaminant deposition in the terrestrial ecosystem.

Activities in 2000-2001

Twenty-five female caribou from the Beverly herd were harvested at Nonacho Lake (61° 59′ N, 109° 28′ W) on April 1 to 3, 2000. The collection was done in collaboration with hunters from the South Slave Metis Tribal Council and the Salt River First Nation # 195. Liver and kidney from a subset of 20 animals were analyzed for metals and radionuclides.

Metals were analyzed by inductively coupled plasma mass spectrometry by the Canadian Association for Environmental Analytical Laboratories-accredited Envirotest Laboratories in Edmonton, AB, using standard methods recommended by the United States Environmental Protection Agency and the Canadian Council of Ministers of the Environment. Quality assurance and quality control of the analyses included blanks, spiked samples, reference materials (dogfish liver) and duplicates. Radionuclide analyses will be conducted at Whiteshell Laboratory in Pinawa, MB, as per Macdonald et al. (1996). Gamma-emitting radionuclides (^{137}Cs, ^{40}K, ^{226}Ra, ^{210}Pb, ^{232}Th) were analyzed using a p-type well detector in tissue ashed at approximately 500°C. ^{210}Po was analyzed by alpha spectrometry using a ^{209}Po tracer, after plating onto silver discs. ^{210}Po concentration at the time of sampling was calculated as the sum of the supported fraction at the time of plating (^{210}Pb concentration) and the unsupported fraction, corrected for decay from counting date to plating date.

Mean values for all metal and radionuclide data were calculated with log transformed data, and are reported as geometric means with geometric standard deviations. Means are calculated for elements with detectable amounts in > 50% of the samples. Sets of samples with < 50% above detection limits are reported at the detection limit.

Results

Data on the body size, organ weights and some morphometric measurements that were collected at the time of harvest are presented in Table 1. Ages are not available at this time but should be available later in 2001. The body (162 to 207 kg) and carcass (88 to 124 kg) weights and morphometric measurements indicate relatively uniform body size within the harvested animals.

The concentrations of metals in liver and kidney are reported in Table 2. The average levels of antimony, arsenic, chromium, nickel, silver, tin and thallium were below detection limits in both tissues. Beryllium was below the 0.2 mg·kg^{-1} detection limit in all liver and kidney samples. Average Cd levels in kidney were 45.6 mg·kg^{-1} dry wt, or about 10 mg·kg^{-1} wet wt, and reached a maximum concentration of 209 mg·kg^{-1} dry wt in one animal. Total Hg was detected in all samples except for one liver sample, and ranged from 4.4 to 11 mg·kg^{-1} dry wt.

Six essential metals were also measured in 22 blood serum samples (Table 3). The levels of each metal are relatively uniform between samples, except for manganese, which included one individual with 1.59 mg·kg^{-1}, considerably higher than all other samples. This outlier could have been caused by contamination of the sample vial. Molybdenum was only detected in 12 of 22 samples, despite an estimated detection limit of 0.001 mg·kg^{-1}. Gamma spectroscopy reported detectable levels of three key nuclides (Table 4). ^{137}Cs was detected in all samples and ranged as high as 294 Bg·kg^{-1} in kidney, with a geometric mean value of 247 Bq·kg^{-1} wet wt. A mean ^{137}Cs level of 93 Bq·kg^{-1} wet wt was observed in liver. ^{210}Pb was considerably higher in liver than kidney, with an average concentration of 154 Bq·kg^{-1} in liver. The same general relationship was observed for ^{210}Po, with the concentration in liver (346 Bq·kg^{-1}) being about twice as high as in kidney (159 Bq·kg^{-1}). ^{226}Ra was observed in several kidney samples, giving a mean of 2.58 Bq·kg^{-1}. The other major gamma emitting nuclides of ^{232}Th, ^{241}Am and ^{235}U were not observed in any samples.

Table 1. Average morphometrics of 25 female caribou from the Beverly herd collected on April 1, 2000[1]

Measurement	Geometric mean	Geometric standard deviation	Range
Body weight (kg)	187	175 - 199	162 - 207
Carcass weight (kg)	101	93 - 110	88 - 124
Total body length (cm)	167	160 - 174	154 - 185
Chest girth (cm)	116	113 - 120	110 - 122
Back fat (mm)	20	11 - 35	trace - 45
Liver weight (g)	913	840 - 993	787 - 1083
Heart weight (g)	759	696 - 829	646 - 858
Total kidney (g)	158	145 - 172	127 - 179
Total kidney fat (g)	122	85 - 174	59 - 220
Femur weight (g)	331	307 - 357	266 - 379
Femur length (cm)	28	27 - 28	26 - 29
Metatarsus weight (g)	215	195 - 238	148 - 249
Metatarsus length (cm)	30	29 - 31	27 - 31

[1] Tissues from a subset of 20 animals were analyzed for metals and radionuclides.

Discussion and Conclusions

Kidney and back fat, which are indicators of the general health of the caribou at the time of sampling, show a normal range of variation and show that most of the females had good fat reserves at the end of the winter. For example, back fat, a key energy source, varies from trace levels to 45 mm in depth, and sizeable amounts of fat are present on the kidneys. This is an indication that the animals were in reasonable health and nutritional status at the time of harvest.

Baseline contaminant levels were first established in 10 major barren-ground caribou herds across the NWT between 1991 and 1995 (Elkin and Bethke 1995, Macdonald et al. 1996). A wide range of metal, radionuclide and organochlorine contaminants were found in herds across the North. Some caribou are known to accumulate high concentrations of Cd in their kidneys and liver, and kidney levels have been shown to increase with age. The levels of Cd reported here for the Beverly herd are at the top of the range of values reported for caribou in the NWT and Nunavut, but are lower than the extreme levels found in mineralized areas of the Yukon. These Cd levels may be considered "normal background" in caribou, as relatively high levels are seen on a circumpolar basis. But they exceed Canadian environmental quality guidelines (30 μg·g^{-1}) for wildlife (Muir et al. 1999) and, in some individual animals, exceed threshold values believed to cause kidney dysfunction.

Baseline levels were also established for aluminum (Al), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), Hg, nickel (Ni) and zinc (Zn). While levels of these metals were generally within normal ranges, there was some variation both between and within herds with elevated levels of some metals at different sites. Ongoing monitoring will include these metals to examine spatial patterns, temporal trends and potential for elevated tissue residues of individual metals within different herds.

In a survey of radionuclides in 15 caribou herds throughout the Arctic, Macdonald et al. (1996) reported high levels of ^{210}Pb and ^{210}Po in some herds, consistent with results of other studies (Thomas et al. 1994). The highest levels of these ^{238}U decay products have been observed in south Baffin Island caribou, where mean concentrations of ^{210}Pb and the alpha-emitter ^{210}Po exceeded 1000 Bq·kg^{-1} wet wt in liver and bone, with one individual exceeding 3500 Bq·kg^{-1} of Pb^{210} and Po^{210} in bone. The doses is some herds are approaching levels at which effects are expected in some individuals, although no evidence of effects due to radioactivity have been documented (Macdonald et al. 1996).

This study provides further support for the general observation that, although metal and radionuclides levels may occasionally reach concentrations which could be toxic to individual animals, they probably do not reach levels at which the populations are affected. The high levels observed in some animals may indicate variation between animals in the ability to accumulate metals or due to differences in diet. However, the presence of high values in some animals warrants continued monitoring for human exposure and caribou health purposes. There is clearly large variation in the

Table 2. Geometric mean concentration, geometric standard deviation (GSD) and range of metals in liver and kidney[1]

		Liver (mg·kg^{-1} dry wt)				Kidney (mg·kg^{-1} dry wt)			
Metal	**Symbol**	**Number detectable**	**Mean**	**GSD**	**Range**	**Number detectable**	**Mean**	**GSD**	**Range**
Aluminum	Al	12	5.6	2.01 - 15.7	4.0 - 36.0	20	7.4	2.7 - 20.3	6 - 43
Arsenic	As	2	< 0.2	—	< 0.2 - 0.2	3	< 0.2	—	< 0.2 - 0.4
Barium	Ba	20	1.1	0.65 - 1.76	0.6 - 3.6	20	5.3	3.8 - 7.4	3.24 - 13.3
Calcium	Ca	20	177	121 - 259	110 - 480	20	455	385 - 536	350 - 590
Cadmium	Cd	20	5.2	3.4 - 8.1	1.9 - 9.7	20	45.6	24.9 - 83.4	14.2 - 209
Cobalt	Co	20	0.26	0.19 - 0.34	0.18 - 0.57	20	0.3	0.2 - 0.5	0.19 - 0.88
Chromium	Cr	9	< 0.2	—	< 0.2 - 1.4	9	< 0.2	—	< 0.2 - 2.7
Copper	Cu	20	18.5	10.0 - 34.1	10.1 - 112	20	21.9	16.7 - 28.7	16.5 - 47.1
Iron	Fe	20	1374	752 - 2 509	667 - 4 840	20	300	200 - 451	161 - 697
Potassium	K	20	10 023	7 568 - 13 275	7 700 - 21 700	18	12 902	10 701- 15 555	10 900 - 21 300
Magnesium	Mg	20	646	608 - 688	551 - 715	20	827	780 - 876	735 - 893
Manganese	Mn	20	11.4	8.4 - 15.7	7.2 - 27.0	20	9.0	7.2 - 11.3	6.38 - 14.7
Mercury	Hg	19	0.7	0.28 - 1.78	< 0.5 - 5.0	20	6.2	4.6 - 8.2	4.4 - 11
Molybdenum	Mo	20	2.40	1.7 - 3.4	1.7 - 5.9	20	0.9	0.5 - 1.4	0.44 - 2.94
Sodium	Na	20	3187	2 589 - 3 923	2 380 - 5 240	20	7594	6 704 - 8 603	6 040 - 9 670
Nickel	Ni	6	< 0.08	—	< 0.08 - 0.50	12	0.11	0.04 - 0.33	< 0.08 - 0.88
Phosphorus	P	20	12 085	11 488 - 12 714	11 100 - 13 500	20	12 213	10 967 - 13 600	10 400 - 17 800
Lead	Pb	20	1.10	0.60 - 1.95	0.41 - 4.45	20	0.55	0.34 - 0.89	0.26 - 1.86
Selenium	Se	20	1.00	0.76 - 1.45	0.80 - 2.40	20	4.9	3.7 - 6.6	3.7 - 9.3
Silver	Ag	7	< 0.08	—	< 0.08 - 0.3	0	< 0.08	—	—
Strontium	Sr	20	0.23	0.15 - 0.35	0.13 - 0.58	20	0.6	0.5 - 0.9	0.41 - 1.38
Titanium	Ti	19	0.55	0.16 - 1.97	0.10 - 6.93	19	0.9	0.3 - 2.6	0.3 - 3.01
Tin	Sn	2	< 0.08	—	< 0.08 - 0.37	3	< 0.08	—	< 0.08 - 0.55
Thallium	Tl	0	< 0.04	—	—	18	0.05	0.03 - 0.08	< 0.04 - 0.11
Vanadium	V	3	< 0.08	—	< 0.08 - 0.23	5	< 0.08	—	< 0.08 - 0.25
Zinc	Zn	20	87.7	68.3 - 113	62.8 - 140	20	121	92 - 159	89.7 - 247

[1] Potassium values were not reported for two kidney samples, giving a sample size of 18. Beryllium (DL = 0.2 mg·kg^{-1}) was not detected in any sample. Antimony (DL = 0.04 mg·kg^{-1}) was reported in one kidney sample at a concentration of 0.06 mg·kg^{-1}.

Table 3. Major element concentration in caribou blood serum[1]

Element	Number Detectable (max = 22)	Geometric Mean (mg·kg^{-1})	Geometric standard deviation	Range
Magnesium	22	25.5	22.8 - 28.5	18.3 - 31.4
Copper	22	0.34	0.26 - 0.45	0.19 - 0.58
Zinc	22	0.82	0.43 - 1.57	0.22 - 3.41
Molybdenum	12	0.008	0.003 - 0.018	< 0.001 - 0.05
Iron	22	6.72	4.19 - 10.8	3.5 - 16.9
Manganese	22	0.008	0.001 - 0.062	0.001 - 1.59

[1] Analysis was conducted by the Wildlife Toxicology group at the University of Saskatchewan.

Table 4. Gamma-emitting radionuclides and ^{210}Po in liver and kidney in the Beverly herd[1]

	Liver (Bq·kg^{-1} wet wt)		Kidney (Bq·kg^{-1} wet wt)	
	Mean	SD	Mean	SD
Dry weight (%)[2]	29.0	1.4	20.9	0.7
Ash weight (%)[2]	1.29	0.11	1.60	0.62
^{40}K	92	85 - 100	85	76 - 96
^{137}Cs	93	78 - 111	247	207 - 294
^{210}Pb	154	86 - 276	63	49 - 82
^{210}Po[3]	346	222 - 540	159	117 - 216
^{232}Th	<1.61	—	< 3.53	—
^{226}Ra	< 1.43	—	2.58	1.27 - 5.25
^{241}Am	< 0.62	—	< 1.27	—
^{235}U	< 2.87	—	< 6.14	—

[1] Radionuclide concentrations are in Bq·kg^{-1} wet wt.

[2] Reported values are arithmetic means and standard deviations.

[3] Analyzed by alpha spectrometry.

concentration of some metals between herds, probably as a result of uneven distribution between regions in lichen or deposition from the atmosphere. Both Cd and Hg remain significant concerns of Northerners since elevated levels could result in effects in the animals and exposure of people to the contaminants.

Project Completion Date

March 31, 2001. Caribou monitoring is ongoing through other Northern Contaminants Program projects.

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An Investigation of Factors Affecting High Mercury Concentrations in Predatory Fish in the Mackenzie River Basin

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Abstract

We had a productive research year on this study. Our research effort consisted of completing the analyses from samples collected in 1999 and in conducting new sampling in Tsesto, Sibbeston and Willow Lakes, in addition to visiting Cli and Little Doctor Lakes again. Mercury concentrations are not high in the water of these lakes. As well, these lakes do not have many of the limnological conditions that favour relatively high mercury methylation rates. In particular, the lakes are not acidic. We have re-examined the fish collected during the original 1996-1999 stock assessment studies to determine if high mercury levels are associated with their feeding behaviours and/or age. We note that the fish in many of the lakes are relatively old. Mercury concentrations in predatory fish do not approach 0.5 $\mu g \cdot g^{-1}$ until these fish approach 10 years of age. Fish also grow more slowly than in more southern regions and so the potential for growth dilution is less. Increased harvesting of larger fish may improve fish growth rates and lower mercury levels.

Key Project Messages

1. We have expanded our mercury (Hg) study to investigate Tsetso, Sibbeston, and Willow Lakes, in addition to our continuing work on Cli and Little Doctor Lakes.
2. We conducted laboratory studies that suggest Hg is transformed more rapidly into forms concentrated by the fish in coloured streams than in the clear streams flowing into Cli Lake.
3. Overall, our five study lakes do not appear to have conditions that are especially favourable for Hg to accumulate at a fast rate in predatory fish. Mercury

concentrations are not very high in the water and high Hg lakes are not small and acidic.

4. We have conducted more studies of the fish that were analyzed during the 1996-1999 stock assessment studies. It is starting to look like the fish have high Hg concentrations in some lakes because they are old and slow growing. Predatory fish start to approach a Hg concentration of 0.5 $\mu g \cdot g^{-1}$, the limit established for the commercial sale of fish, at about 10 to 12 years of age when they are eating more and more small, forage fish.

Objectives

1. Continue investigations of the factors affecting elevated Hg levels in predatory fish in Cli and Little Doctor Lakes.
2. Conduct preliminary studies of methylation and demethylation rates in Cli Lake stream sediments.
3. Conduct baseline limnological and Hg studies at Sibbeston and Tsetso Lakes, upstream of Little Doctor Lake, and Willow Lake, located on the Horne Plateau.
4. Investigate the role of trophic feeding in affecting Hg levels in predatory fish in the five study lakes.

Introduction

For many years, the Department of Fisheries and Oceans has been working with First Nations communities in the Mackenzie River Basin on stock assessment studies. Several lakes have been sampled and fish species composition, length, weight and age determined as part of these studies. In addition, Hg concentrations have been determined in these fish. Researchers were surprised to learn that predatory fish in many of these lakes have Hg concentrations that exceed the 0.5 $\mu g \cdot g^{-1}$ limit established for the commercial sale of fish and the 0.2 $\mu g \cdot g^{-1}$ limit established for the frequent consumption of fish. As a consequence of these high levels, Health Canada has issued consumption advisories for many of these lakes.

It is not known why Hg levels are high in predatory fish in some lakes and not others. These lakes are located in pristine, undeveloped regions in the Mackenzie River Basin. Therefore, elevated Hg levels cannot be due to localized anthropogenic factors such as industrial waste discharges, flooding caused when reservoirs are created, or by disturbances in the watershed as a result of logging (Jackson 1986, 1991, Tremblay and Lucotte 1997, Garcia and Carignan 2000). Thus, naturally-occurring limnological features such as low pH, high dissolved organic carbon concentrations, humic stained water, a large watershed size, and shallow lake depths (Winfrey and Rudd 1990, Cope et al. 1990, Miskimmin et al. 1992, Parkman and Meili 1993, Bodaly et al. 1993) may be more important in affecting Hg levels in predatory fish. Local geological features have been shown to be important in some settings and may be important in some of the lakes in the Mackenzie River Basin (Shilts and Coker 1995). Mercury concentrations also increase with fish size and age (Munn and Short 1997) and with trophic feeding (Vander Zanden and Rasmussen 1996). Therefore, elevated Hg levels may be a function of the population structure and feeding characteristics of the fish populations in high Hg lakes. Our study is designed to elucidate these issues.

Initially, our research effort focussed on the limnological investigation of Cli and Little Doctor Lakes located to the west of Fort Simpson in the Nahanni Mountains. Advisories have been issued for the consumption of lake trout in Cli Lake and walleye and pike in Little Doctor Lake. In 1998 and 1999, we obtained new limnological information on these lakes including lake bathymetry (depths), watershed size, stream inflows, pH, dissolved organic carbon concentrations, water colour, ionic composition and nutrients. Mercury was measured in Cli Lake stream inflows (the data from the first year were suspect) and in sediments. Of particular interest was the possibility that elevated Hg concentrations were associated with some aspect of geological fault lines that underlie both lakes. Limited stable isotope and Hg studies were conducted on the Cli Lake food web. In comparison to other studies where elevated Hg concentrations have been reported in fish and other components of the environment, Hg levels were not especially high in Cli Lake stream and lake water, sediments and invertebrates. A dated sediment core from Cli Lake revealed that Hg flux rates to Cli Lake sediments have increased in recent decades, as has been observed in many other regions of the Northwest Territories (Lockhart et al. 1995). In 2000, we broadened our study to include three additional lakes – Tsetso, Sibbeston and Willow Lakes. Tsetso and Sibbeston Lakes were selected because they drain into Little Doctor Lake and because Hg levels were lower in whitefish in these lakes than in Little Doctor Lake (Lockhart and Evans 1999). These lakes also contain pike and walleye populations but not lake trout. Willow Lake was selected because it contained lake trout that had lower Hg concentrations than Little Doctor and Cli Lake.

Activities in 2000-2001

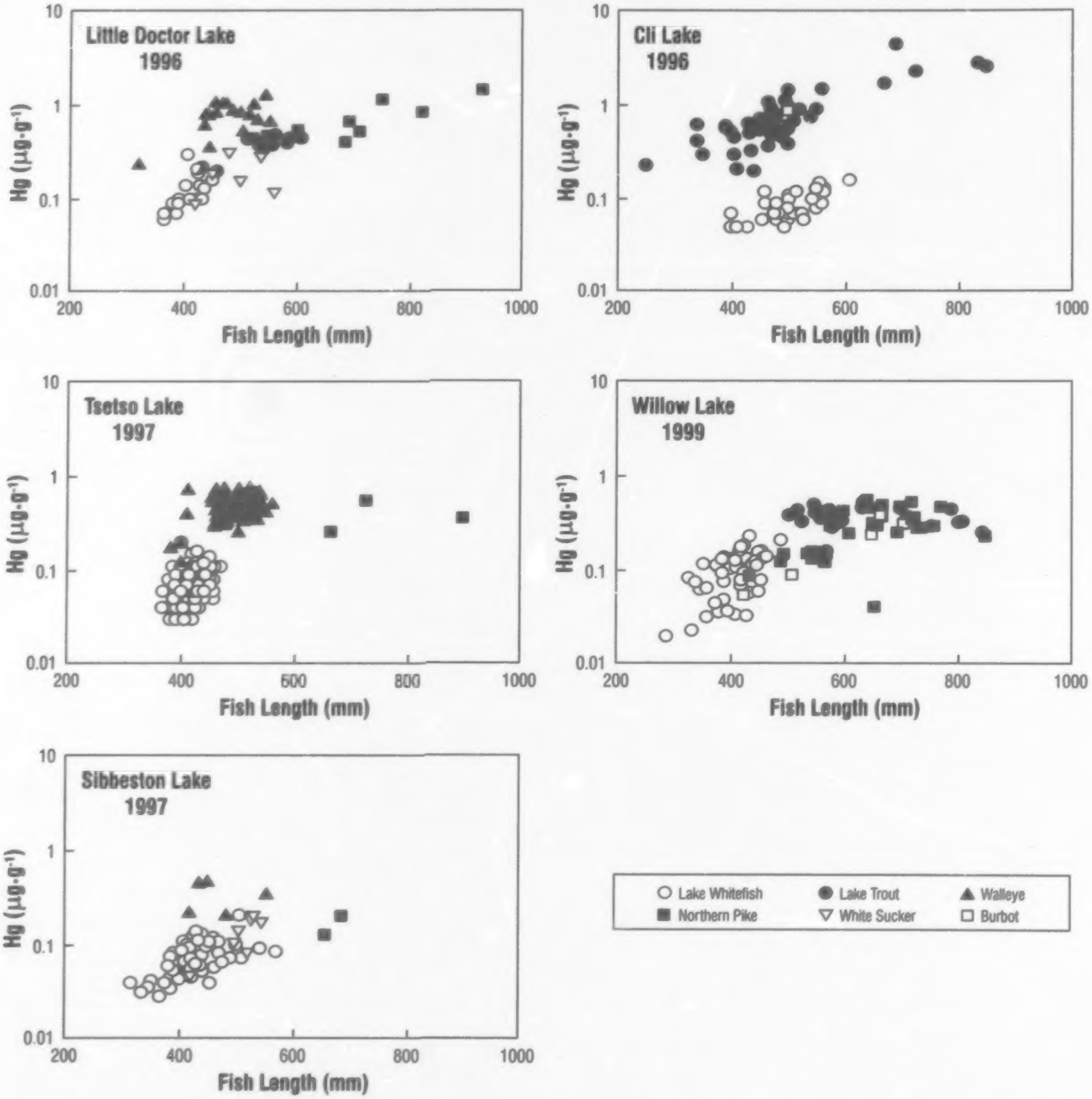
Research activity in 2000 focussed on the completion of analyses of samples from the 1999 field season and the new analysis of archived fish samples from the original stock assessment studies. These activities continue. In

August 2000, we conducted new and additional research sampling of the five study lakes (Cli, Little Doctor, Tsetso, Sibbeston and Willow) in order to elucidate the potential limnological factors affecting elevated Hg levels in predatory fish in some but not all of these lakes. Weather was poor, with rain and strong winds during much of the trip, so that not all of the sampling could be completed during this 2-week period.

Results and Discussion

The five study lakes have different fish communities, with lake trout found only in Cli, Little Doctor and Willow Lakes during the original stock assessment studies (Figure 1). While pike were numerous in the original stock assessment study of Little Doctor Lake, small numbers were collected in Tsetso (three fish) and Sibbeston (two fish) Lakes. We have collected small numbers of pike from Cli Lake during

Figure 1. Muscle mercury concentrations versus length of fish from lakes in the Mackenzie River Basin



our various summer field studies. Walleye have been collected in large numbers in the highly-coloured waters of Little Doctor and Tsetso Lakes with smaller numbers (five fish) collected from Sibbeston Lake. Walleye have not been collected from Cli and Willow Lakes. Therefore, whitefish is the single species common to all five lakes. Interlake comparisons of Hg as a function of the limnological features of the study lakes are most effectively made with this species. Continuing Northern Contaminants Program research in 2001 and 2002 will help increase the lake sample size for more effective interlake predatory fish comparisons. A related Toxic Substances Research Initiative project is investigating the biomagnification of organochlorine contaminants and Hg in the northern regions of the provinces and will allow for an expanded data set for lake trout comparisons. This project is led by D. Muir with M. Evans investigating lake trout populations in northern Saskatchewan and Alberta (i.e. in the lower portions of the Mackenzie River Basin).

Whitefish from the five study lakes varied markedly in mean length and Hg concentration (Table 1). Cli Lake had the largest mean whitefish size, and Little Doctor and Willow Lakes had the smallest. Mean Hg concentration, adjusted for fish length, was highest in Little Doctor Lake and lowest in its two upstream lakes. Adjusted mean Hg concentrations were higher in Willow Lake than Cli Lake whitefish. Cli Lake whitefish, while large, were relatively young; growth dilution may have been a factor in affecting the somewhat lower Hg body burdens (unadjusted) in Cli Lake whitefish. In contrast, Little Doctor Lake whitefish were small relative to their age. Elevated Hg levels may be related, in part, to low whitefish growth rates in this deep, highly coloured lake although other factors relating to Hg methylation also must be important.

Little Doctor Lake has the largest drainage basin while Tsetso Lake has the smallest (calculations have not been performed for Willow Lake). Lake size has been implicated as a factor in affecting Hg concentrations in predatory fish (Bodaly et al. 1993) (i.e. Hg concentrations tend to be higher in fish in smaller than larger lakes). Our five study lakes varied markedly in size from Tsetso Lake, with a surface area of 12 km^2, to Willow Lake, with a surface area of 152 km^2 (Table 2). In contrast to the Bodaly et al. (1993) study, whitefish inhabiting the smallest lakes had the lowest mean (adjusted) Hg concentration while higher Hg concentrations in whitefish were observed in the larger lakes.

Wetland area is an important variable affecting Hg concentrations in fish in some regions (St. Louis et al. 1994). Little Doctor Lake, with the largest wetland area, had the highest adjusted Hg concentration in whitefish. However, Hg concentrations also were relatively high in Cli Lake whitefish, a lake with a small drainage area, and low in Sibbeston Lake, a lake with a relatively large wetland area. Overall, there is not a strong relationship between Hg levels in whitefish and factors such as lake size, drainage basin area, and wetland area. However, such relationships may emerge with the inclusion of more lakes into our data

Table 1. Mean (± standard deviation) length, age and mercury concentration[1] in whitefish for the five study lakes

Lake	Mean length (mm)	Mean age (y)	Mean Hg ($\mu g \cdot g^{-1}$)	Standardized Hg concentration
Cli	498.5 ± 44.4	7.5 ± 2.6	0.08 ± 0.03	0.06
Little Doctor	406.9 ± 25.7	10.0 ± 1.8	0.13 ± 0.06	0.11
Tsetso	421.1 ± 22.5	14.6 ± 5.0	0.07 ± 0.03	0.03
Sibbeston	421.8 ± 3.3	11.9 ± 5.0	0.07 ± 0.02	0.04
Willow	408.0 ± 46.4	8.8 ± 2.5	0.09 ± 0.04	0.08

[1] Mean mercury concentration for a 400 mm fish

Table 2. General physical features of the five study lakes

Lake	Surface area (km^2)	Drainage basin area (km^2)	Ratio (drainage area/lake area)	Wetland area (km^2)	% Drainage area as wetland
Cli	43	190	4.8	4	2.1
Little Doctor	21	1438	68.5	253	17.6
Tsetso	12	144	12.0	16	11.1
Sibbeston	30	916	30.5	168	18.3
Willow	152	—	—	—	—

set. Additional standardization of the whitefish data for age, trophic feeding, and growth rates may also clarify these relationships.

During our August 2000 sampling, we obtained new limnological information on Willow, Tsetso and Sibbeston Lakes and additional data for Little Doctor and Cli Lakes. This allowed us to explore the relationship between Hg levels in fish and factors such as pH, dissolved organic carbon (DOC), and other variables that affect Hg transformations and lake productivity.

It was not possible to conduct bathymetric (depth) mapping of Willow Lake because of the poor weather that limited boat travel on this very large lake. Willow Lake is assumed to be at least 20 m deep (Table 3) because of its size and the fact that lake trout are abundant in the lake. The lake is irregular in shape with several small bays. Sibbeston Lake was mapped and was shallow with most depths at 2 to 3 m. There were limited areas where depth reached 8 m. Extensive weed beds were evident in the main body of the lake from the air. There also were numerous shallow bays with lush macrophyte growth including yellow lily pads. Tsetso Lake is a small, circular lake with one major inflow. It was visited on a day trip and very poor weather also prevented depth mapping of this lake. However, the lake was shallow with most depths of 2 to 3 m. A deeper area of 5 m also was located in the region where fish are traditionally harvested in winter. As noted in Evans and Lockhart (2000), Cli and Little Doctor lakes are very deep.

At each lake, a standard series of water column measurements were made including temperature, specific conductivity, pH, and water clarity (Table 3). There was an unexpected inverse relationship between surface water temperatures and lake size. Intuitively, shallowest lakes would have the warmest surface water temperatures. However, Tsetso Lake, the smallest and shallowest lake, had the coldest waters while Little Doctor Lake, the deepest lake, had the warmest surface waters. The cooler waters of Sibbeston and Tsetso lakes are suggestive of strong groundwater inputs as has been observed in Cli Lake (see below). In the Bodaly et al. (1993) study, higher Hg concentrations in the smaller lakes was related to warmer water temperatures. Methylation rates increase with temperature while demethylation rates decrease. While the temperature differences in our study are small and based on a single observation, they may suggest that low Hg concentrations in whitefish in Tsetso and Sibbeston Lakes are, in part, related to their cooler temperatures which result in lower methylation/demethylation (M/D) ratios than in the larger lakes. Little Doctor and Cli Lakes, located in the Nahanni Mountain range, had the highest conductivity, presumably due to the incorporation of dissolved salts in the runoff down the limestone mountain slopes. Tsetso Lake had the lowest conductivity. All five lakes had similar pH values and were slightly basic. These basic conditions were not favourable for high Hg methylation rates: these rates decline with increasing pH and tend to be highest in acidic lakes (Winfrey and Rudd 1990). Low water clarity was, in large measure, associated with humic-stained waters.

A series of water chemistry measurements were made at each lake including nutrients, dissolved organic carbon and total Hg. Plankton samples also were collected. Based on total phosphorus concentration, Cli Lake was the least productive lake. It also had relatively high nitrate concentrations. DOC concentrations were lowest in Cli Lake and highest in Little Doctor and Sibbeston Lakes; concentrations also were high in Tsetso and Willow Lakes. According to Miskimmin et al. (1992), Hg methylation (M) rates decrease and demethylation (D) rates increase with increasing DOC concentrations. The largest increase in demethylation rates occurred between 6.7 and 9.1 mg·L^{-1} DOC. Because Little Doctor Lake has basic waters and high DOC concentrations, the M/D ratio is likely to be low in this lake. Watershed inputs of methylmercury (MeHg) may be important (Miskimmin et al. 1992) for Cli and Little Doctor Lakes although high DOC and basic pH also characterize the two primary feeder lakes (Tsetso, Sibbeston) into Little Doctor Lake. Overall, elevated Hg levels in predatory fish in lakes such as Cli and Little Doctor do not appear to be associated with in situ

Table 3. General physical-chemical features of the lake waters, August 2000

Lake	Maximum depth (m)	Surface temperature (°C)	Specific conductivity (μS·cm^{-1})	pH	Secchi disc (m)
Cli	83	17.2	201	8.2	8.4
Little Doctor	170	18.7	155	8.0	1.6
Tsetso	5	15.8	82.3	8.2	1.7
Sibbeston	8	17.5	121	8.0	1.1
Willow	> 20	16.6	120	7.9	< 3.8

limnological conditions such as low pH and moderately low DOC concentrations which favour Hg methylation rates.

Mercury concentrations are not high in the water column of the five study lakes and are remarkably similar to one another (Table 4). As previously noted, Hg flux rates to Cli Lake, based on a sediment core analysis, are low and comparable to Lac Belot and Great Bear Lake where Hg concentrations are low in lake trout.

As in August 1999, we sampled a series of creeks flowing into Cli Lake for temperature, conductivity, pH, turbidity and Hg (Table 5). Creeks were substantially colder than lake water, indicating that they were fed by cold groundwaters. Creeks also were colder in August 2000 than in August 1999. The three creeks flowing down the mountains had higher conductivity and clearer waters than the humic-stained, lower conductivity waters draining the flatter wetland areas to the east. Nevertheless, all creeks were slightly basic. Total Hg concentrations were low.

Sediment samples were collected from six creeks and these samples, along with a lake sediment sample, were sent to T. Jackson (NWRI, Burlington) for methylation experiments. Two experiments were conducted over a 7-day period and a third over a 14-day period. These data are still being analyzed. However, highest carbon dioxide production was associated with sediments collected from the humic-stained creeks (i.e. creeks 9, 12 and 17) (Table 6). Preliminary MeHg data (not shown) also show the MeHg production rates are highest in the humic-stained creeks. The 2-week experiment, utilizing the lake sediment sample determined that carbon dioxide continued to be produced during the length of the experiment, suggesting that methylation predominated over demethylation. Although methylation rates apparently were lower at the single Cli Lake site examined than the three creek sites, the lake itself may be more important in terms of Hg methylation given its considerably larger surface area.

A broad series of invertebrate samples were collected in the littoral region of each of the study lakes in summer 2000. Where possible, samples were collected in weedy marshy areas and in rocky areas where Hg levels and/or methylation rates possibly may differ. In addition, in Little Doctor Lake, invertebrates were collected in various rocky areas in different reaches of the mountain ranges. Organisms included snails, caddisflies, mayflies, stoneflies, beetles, leeches, amphipods and corixids. Invertebrates have been identified to species. A subset from each lake is being analyzed for total Hg and stable isotopes. Methylmercury analyses will be performed on a subset of these samples.

Table 4. Water chemistry measurements in the five study lakes, August 2000

Lake	Total P ($\mu g \cdot L^{-1}$)	Ammonia ($\mu g \cdot L^{-1}$)	Nitrate-nitrite ($\mu g \cdot L^{-1}$)	Dissolved nitrogen ($\mu g \cdot L^{-1}$)	Dissolved organic carbon ($mg \cdot L^{-1}$)	Mercury ($ng \cdot L^{-1}$)
Cli	7	6	268	443	4.8	1.04
Little Doctor	14	< 5	70	443	15.9	1.05
Tsetso	13	8	51	416	12.7	0.86
Sibbeston	13	< 5	< 10	468	14.6	0.96
Willow	12	13	< 10	381	10.2	1.03

Table 5. Physical-chemical features of six creeks flowing into Cli Lake, August 2000

Lake	Temperature (°C)	Specific Conductivity ($\mu S \cdot cm^{-1}$)	pH	Turbidity (NTU[1])	Mercury ($ng \cdot L^{-1}$)
Creek 1	6.0	396	8.1	4.2	1.49
Creek 2	5.1	392	8.4	—	4.16
Creek 3	6.2	204	8.5	—	1.63
Creek 6	5.3	378	8.4	1.4	—
Creek 9	4.6	85.6	8.2	—	2.25
Creek 12	9.0	98	8.1	13.7	—
Creek 17	10.1	139	8.4	1.0	1.3

[1] Nephelometric turbidity unit

Table 6. Carbon dioxide production by creek and lake sediments following 7 days of incubation

Location	Replicate 1 (μmol)	Replicate 2 (μmol)	Mean (μmol)
Cli Lake (off creek 9)	71.0	70.5	70.8
Clear creeks			
Creek 2	51.1	44.1	47.6
Creek 3	71.0	78.2	74.6
Creek 6	14.8	20.3	17.6
Mean (± SD)			46.6 ± 28.5
Humic-stained creeks			
Creek 9	139.4	114.9	127.2
Creek 12	140.0	123.8	131.9
Creek 17	156.8	138.3	147.6
Mean (± SD)			135.6 ± 10.7

Table 7. The proportion of variance explained, r^2, between mercury concentration in fish and length, age and ^{15}N for various species and lakes[1]

Lake	Length	Age	^{15}N
Whitefish			
Cli	0.11	0.68	0.27
Little Doctor	0.69	0.41	0.15
Tsetso	0.15	0.38	0.03
Sibbeston	0.44	0.43	0.02
Willow	0.28	0.01	0.24
Pike			
Cli	—	—	
Little Doctor	0.69	0.83	0.73
Tsetso	0.89	0.57	0.11
Sibbeston	- (2 fish run)	- (2 fish run)	- (2 fish run)
Willow	0.30	—	0.19
Walleye			
Cli	—	—	
Little Doctor	0.01	0.02	0.41
Tsetso	0.16	0.54	0.14
Sibbeston	0.00	0.54	0.82
Willow	—	—	—
Lake trout			
Cli	0.66	0.69	0.38
Little Doctor	0.44	—	0.07
Willow	0.00	0.02	0.12

[1] The square root of these values gives r, the correlation coefficient.

Mercury and stable isotope analyses have been completed on a series of invertebrate samples collected in various regions of Cli Lake in August 1999. Highest Hg concentrations were found in mysids (210 ng·g^{-1} dry weight), followed by backswimmers (*Notonecta*, 180 ng·g^{-1}), waterboatmen (150 ng·g^{-1}), waterstriders (150 ng·g^{-1}) and plankton (100 ng·g^{-1}). These concentrations are similar to those observed in unimpacted boreal lakes but lower than concentrations associated with flooded reservoir lakes.

A small mesh (1.5 inch) gill net and a beach seine were used to capture small forage fish in summer 2000. A few small pike (seine) were captured in Willow Lake along with larger whitefish, pike and a grayling. Larger walleye, pike, and whitefish were captured in Little Doctor Lake and Sibbeston Lake (gillnet). No additional fish were captured in Tsetso Lake because of time and weather considerations.

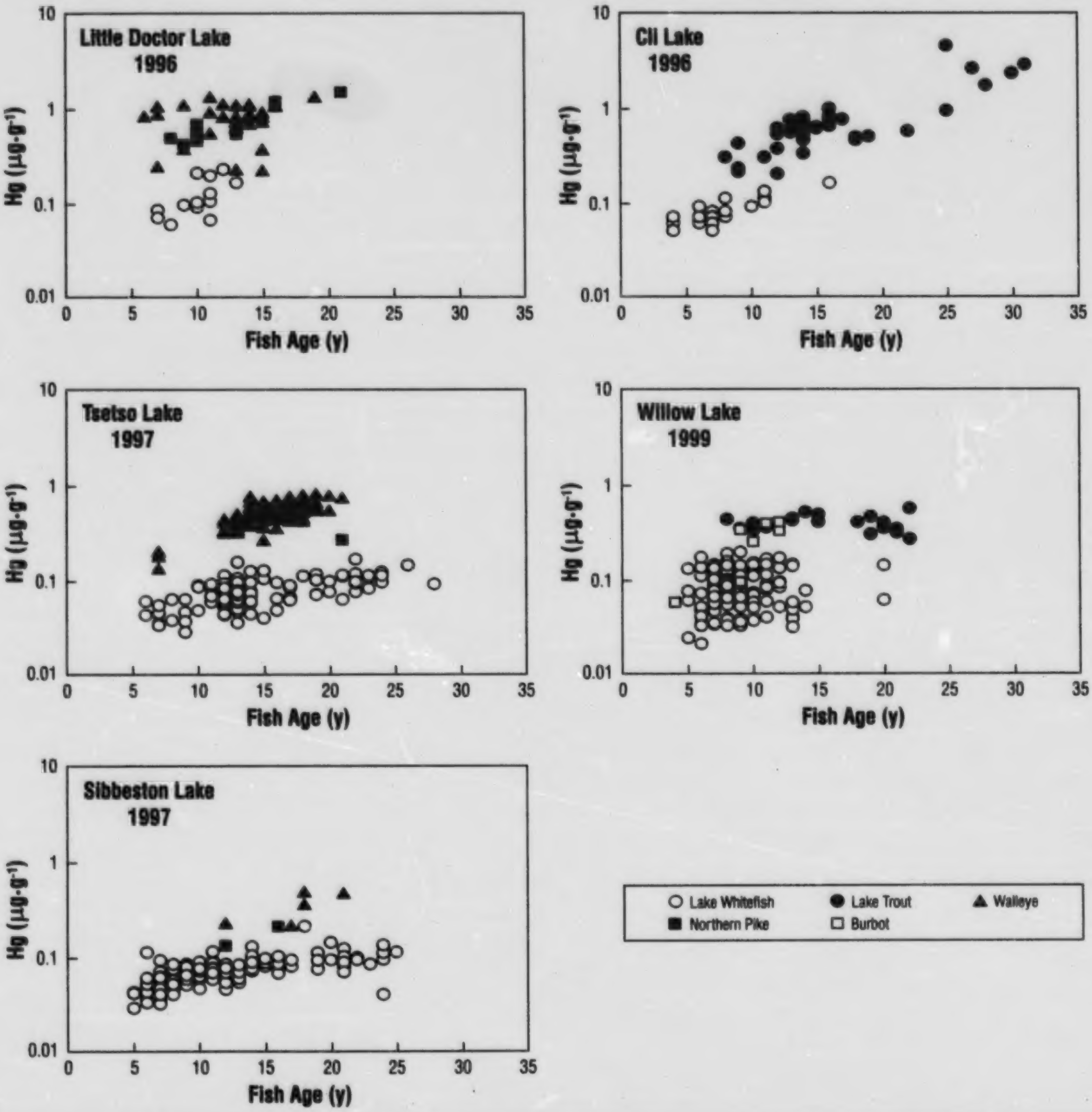
Mercury and stable isotopes have been measured in forage fish collected from the littoral zone of Cli Lake in August 1999 including burbot (16.5 ng·g^{-1}wet weight), whitefish (17.5 ng·g^{-1}), nine-spine sticklebacks (36 ng·g^{-1}), emerald shiners (24 ng·g^{-1}) and spoonhead sculpins (27 ng·g^{-1}). A small northern pike (58 ng·g^{-1}) and burbot (23 ng·g^{-1}) also were analyzed from the Little Doctor Sibbeston River inflow. Adult pike were captured in Cli Lake in 1999 and 2000. For the five fish (from the 1999 collections), Hg concentrations analyzed ranged from 270 to 470 ng·g^{-1}wet weight and averaged 353 ng·g^{-1}. This mean is similar to that observed in Tsetso (390 ng·g^{-1}) and Willow (280 ng·g^{-1}) lakes, higher than in Sibbeston (160 ng·g^{-1}), but lower than in Little Doctor Lake (390 ng·g^{-1}). In contrast, mean Hg concentrations are higher in Cli Lake (880 ng·g^{-1}) than Little Doctor Lake (390 ng·g^{-1}) suggesting that factors such as fish population structure and trophic feeding may be important modifying variables.

A subset of archived fish samples from the original stock assessment studies was examined for stable isotopes to infer carbon sources (^{13}C) and trophic feeding (^{15}N). In addition, we examined the relationship between Hg concentration and fish length, age, ^{15}N, and overall features of the fish populations. These analyses are continuing. Initial interpretations are as follows.

Considering first Cli Lake, the 1996 stock assessment study captured a fish population dominated by lake trout and whitefish (Figures 1-3). Whitefish (mean length: 499 mm) and lake trout (mean length: 475 mm) populations both exhibited a broad range in size. Whitefish were relatively young (mean age: 7.2 years) while lake trout were older (mean age: 15.7 years) with several trout > 25 years old. ^{15}N averaged 8.4‰ for whitefish and 11.7‰ for lake trout. Mercury concentrations averaged 0.08 $\mu g \cdot g^{-1}$ in whitefish and 0.88 $\mu g \cdot g^{-1}$ in lake trout and increased with fish length, age and ^{15}N. Mercury concentration in lake trout was most strongly correlated with fish age (Table 7). Lake trout began exceeding Hg concentrations of 0.5 $\mu g \cdot g^{-1}$ at about 13.6 years of age and as ^{15}N approached 10.9‰ (i.e. a forage fish dominated diet). Thus, very high Hg concentrations in Cli Lake lake trout appear to be most strongly associated with the fact that fish are both old and feed on small forage fish.

Willow Lake, which is the second lake trout lake in our study, had a 1999 fish population (stock assessment study) dominated by whitefish, pike, and lake trout. Based on the stock assessment studies, whitefish are smaller (mean: 408 mm) than in Cli Lake but older (mean: 8.8 years), with a higher average ^{15}N of 9.6‰ suggesting a lower growth rate and more predaceous feeding than in Cli Lake. Nevertheless, mean Hg concentration (0.09 $\mu g \cdot g^{-1}$) was only slightly higher than in Cli Lake. In contrast, while lake trout were larger in Willow Lake (mean length: 609 mm) than in Cli Lake (mean: 475 mm), they were of

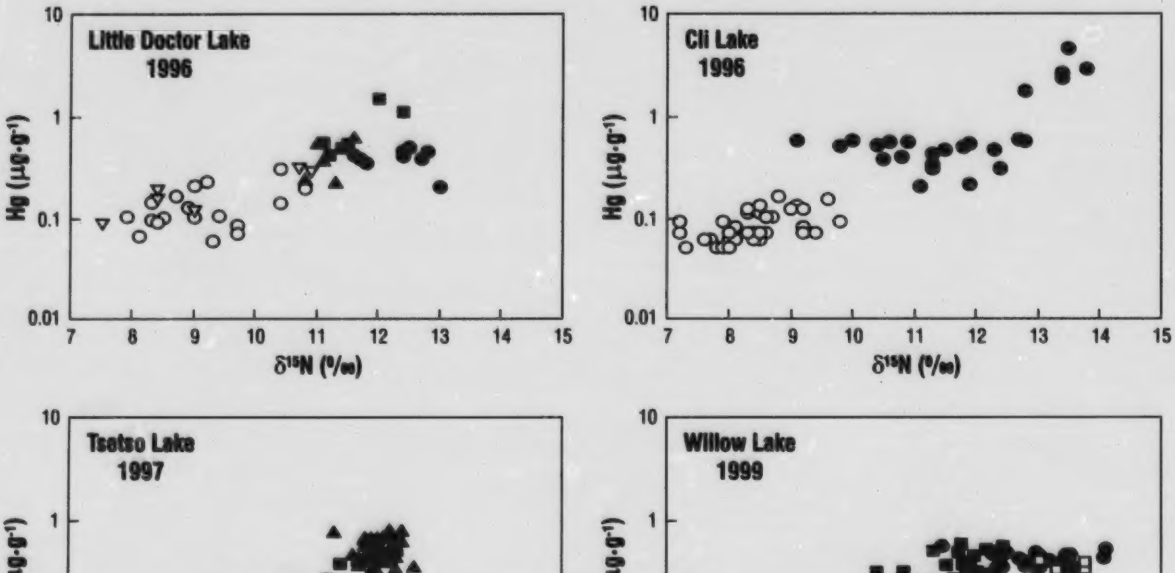
Figure 2. Muscle mercury concentrations versus age of fish from lakes in the Mackenzie River Basin



similar mean age (15.8 years); this suggests that lake trout are growing at a more rapid rate in Willow Lake than Cli Lake. Mercury concentrations also were lower (mean: 0.38 $\mu g \cdot g^{-1}$) despite higher trophic feeding (^{15}N mean = 9.6‰), possibly as a result of growth dilution and/or lower MeHg concentrations in their diet. Mercury levels in lake trout were not strongly related to lake trout length, age or trophic feeding (Table 7). This suggests significant variety in feeding habits. That is, some large and/or older lake trout may consume a greater proportion of invertebrates than smaller and/or younger lake trout which may consume proportionately more fish. Other studies have noted substantial variation in the trophic feeding of fish predators in lakes (Vander Zanden et al. 2000). Willow Lake pike had a mean length of 647 mm and a ^{15}N of 11.7‰; pike were not aged. Mercury concentration (mean: 0.24 $\mu g \cdot g^{-1}$) was most strongly correlated with fish length.

The 1996 Little Doctor Lake fish population (stock assessment studies) was dominated by whitefish (mean length: 497 mm), pike (mean length: 695 mm), walleye (mean length: 474 mm), and lake trout (mean length: 547 mm). Whitefish were similar in size to Cli Lake fish

Figure 3. Muscle mercury concentrations versus stable isotopes in fish from lakes in the Mackenzie River Basin



and larger than in Willow Lake. Pike were larger than in Willow Lake. Lake trout were larger, in average size, than in Cli Lake, due predominately to the absence of smaller trout: very large lake trout were not observed as in Cli Lake. Fish were relatively old with mean fish ages of 10.0 years for whitefish, 12.1 for pike and 13.4 for walleye; lake trout were not aged. ^{15}N averaged 9.1‰, 11.6‰, 11.2‰ and 12.2‰, while Hg concentrations averaged 0.13, 0.77, 0.75 and 0.39 $\mu g \cdot g^{-1}$, respectively. Mercury concentrations were most strongly correlated with age for pike, length for lake trout and ^{15}N for walleye (Table 7). Little Doctor Lake pike approached Hg concentrations of 0.5 $\mu g \cdot g^{-1}$ at approximately 10 years and walleye when ^{15}N approached 11.5‰. For lake trout, the value was 10.5‰ which is similar to the 10.9‰ value for Cli Lake lake trout.

Whitefish, walleye, and a smaller proportion of larger pike dominated the 1997 Tsetso Lake fish population. There was a narrower range in whitefish size (mean 421 mm) than in the other lakes and fish were the oldest with a mean age of 14.6 years. This suggests that whitefish, particularly older fish, had slow growth rates. ^{15}N (mean: 9.6‰) was similar to other lakes, as were Hg concentrations (mean: 0.08 $\mu g \cdot g^{-1}$). Walleye had an average age of 15.6 years, a length of 487 mm and a ^{15}N of 12.0‰, values similar to Little Doctor Lake – while Hg concentration was lower, averaging 0.48 $\mu g \cdot g^{-1}$. Walleye approached a Hg concentration of 0.5 $\mu g \cdot g^{-1}$ at approximately 15.7 years of age and as ^{15}N approached 12.3‰. Similarly, pike were larger (mean: 763 mm), older (mean: 16.7 years) and with similar ^{15}N values (mean: 11.2‰) but lower Hg concentrations (mean: 0.29 $\mu g \cdot g^{-1}$) than pike in Little Doctor Lake. Pike approached a Hg concentration of 0.5 $\mu g \cdot g^{-1}$ at approximately 14.7 years of age and as ^{15}N approaches 10.5.

The Sibbeston Lake fish community was dominated by whitefish which were intermediate in mean size (426 mm) and age (11.9 years) to whitefish in the other study lakes, although the mean ^{15}N value (9.8‰) was the highest. Mean Hg concentration was the lowest (0.07 $\mu g \cdot g^{-1}$). A smaller number of walleye were caught with a mean length of 468 mm, a mean age of 17.2 years and a ^{15}N of 11.3‰. Mercury concentration in walleye was the lowest (0.75 $\mu g \cdot g^{-1}$) of the three lakes. Walleye approached a Hg concentration of 0.5 $\mu g \cdot g^{-1}$ at approximately 15.7 years of age and as ^{15}N approached 11.8‰. Only two pike were captured from Sibbeston Lake during the original study; these fish were relatively small (mean: 631 mm), old (mean: 16.7 years) and with a high ^{15}N (mean: 11.5‰) but a low Hg concentration (0.29 $\mu g \cdot g^{-1}$).

In 2000, we had various community interactions. All of our field sampling was conducted with Ricky Tsetso, our guide during our previous years of sampling. At Willow Lake, an Elder and two community members, including a youth, accompanied us. We also responded to inquiries from Jean Marie River regarding stock assessment and Hg studies in their area. We prepared a draft report on the results of our first 2 years of study and received comments on it during our August field season. This report is being improved and updated.

Conclusions

We had a productive field season in August 2000, conducting new sampling on three lakes and revisiting Cli and Little Doctor Lakes. While ongoing, our study has not shown elevated Hg concentrations in predatory fish in Cli and Little Doctor Lakes to be associated with a combination of low pH and high DOC, as observed in other lakes, nor to high background Hg levels. Nor have our studies suggested that limnological and watershed conditions are such as to favour relatively high Hg methylation and low demethylation rates. Fish age appears to be important because relatively old fish populations dominate many of the lakes; thus fish have been accumulating Hg over many years. Because growth rates are lower than in the more southern regions of their population range, the potential for growth dilution is less. Increased harvesting of larger fish would remove fish with high Hg concentrations from the fish population and may improve growth rates. Fish harvesting has previously been suggested as a means to lower Hg concentrations in fish (Verta 1990).

Expected Project Completion Date

This project is expected to end in 2003.

Acknowledgments

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Spatial and Long-Term Trends in Organic Contaminants and Metals in Fish Species Important to the Commercial, Sports and Domestic Fisheries of Great Slave Lake and the Slave River Ecosystem

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Abstract

This study is the second year of a long-term monitoring program of contaminant trends (PCBs, DDT, toxaphene, mercury, etc.) in lake trout, burbot (loche, maria) and pike (jack) from two regions of Great Slave Lake. The West Basin is strongly affected by inputs from the Slave River while the East Arm is influenced more by atmospheric inputs. In 2000, burbot from the Slave River were added to the study design. In the West Basin, a community fisherman collected pike and burbot near the Slave River inflow and lake trout in the Simpson Island area. In the East Arm, a community member at Lutsel K'e collected these species of fish in the vicinity of the community. Finally, a community member from Fort Smith collected burbot in the Slave River. Ten specimens of the approximately 20 collected of each species from each location were submitted for analyses, which are ongoing, while the remainder is archived. A presentation was given at Lutsel K'e on previous studies conducted from 1994 to 1998, including preliminary 1999 results. Data from 1999 have been received and initial interpretations are presented in this report.

Key Project Messages

1. Lake trout, pike, and burbot were collected from the West Basin and the East Arm in 2000 with the support of community members from Fort Resolution and Lutsel K'e. Burbot were collected from the Slave River with support from Fort Smith.
2. Contaminant analysis of fish collected in 2000 is ongoing.
3. Fish collected in 1999 have been analyzed for contaminants.
4. Metals, such as mercury (Hg), occurred in relatively low concentrations in lake trout, burbot and pike from the two locations in Great Slave Lake in 1999.
5. Organochlorine (OC) concentrations also were low in fish from these two locations. Lower OC concentrations were observed in lake trout and burbot caught from the East Arm in 1999 than in 1993. Continuing research will investigate whether this is a real time trend and the reasons for it.
6. Organochlorine concentrations in fish collected in the West Basin in 1999 are similar to concentrations observed in earlier years. Continuing research will investigate why OC concentrations in fish in the West Basin are similar to those observed in earlier years while declining concentrations may be occurring in fish from the East Arm.

Objectives

1. Develop a cost-effective, long-term monitoring strategy for assessing temporal trends in persistent organic contaminant concentrations (including PCBs, DDT, toxaphene, coplanar PCBs and Hg) in key predatory fish species inhabiting the Great Slave Lake ecosystem, including the Slave River.
2. Assess spatial patterns in contaminant trends and investigate possible causal factors for these patterns, including sources (long-range atmospheric and the Slave River) and food web pathways.
3. Integrate this monitoring program with research and monitoring programs being conducted in the Peace and Athabasca River drainage systems (supported under the Northern River Ecosystem Initiative) and G.A. Stern's Northern Contaminants Program (NCP)-supported burbot monitoring program on the Mackenzie River at Fort Good Hope, Northwest Territories.

Introduction

The NCP has noted that the lack of temporal trend data for contaminants in biota is a significant knowledge gap. Accordingly, it has called for the creation of a long-term biomonitoring program to establish time trends in contaminant concentrations. By establishing monitoring sites, useful information will be provided on whether or not contaminant concentrations are decreasing with reduced use of persistent organic pollutants (POPs) worldwide. For time trends in freshwater environments, fish have been identified as the best organism for biomonitoring of contaminant trends. Several sites are being investigated – including the Mackenzie River at Fort Good Hope, various Yukon lakes and Great Slave Lake, the focus of this study. Great Slave Lake was selected as one of the sites for the long-term biomonitoring of contaminant trends in freshwater fish for the reasons described below.

First, in the mid-1990s, the NCP supported various studies of POPs in Great Slave Lake, including food web biomagnification studies. Biological research was focused at two sites – Fort Resolution, near the Slave River mouth, and Lutsel K'e, in the East Arm and well-removed from a direct Slave River influence (Evans 1994, 1995). Contaminant concentrations tended to be higher in the East Arm than West Basin, possibly because suspended sediments in the Slave River reduce the bioavailability of POPs to biota. Fish collected during these NCP-supported studies are archived; therefore, it is possible to re-examine these archived samples for compounds that were not analyzed or to compare differences between current analytical methods and older methods. Such studies are highly useful and provide for a greater confidence in using older data (Huestis et al. 1996).

Second, Great Slave Lake is strongly influenced by the Slave River, formed by the confluence of the Peace and Athabasca rivers. Increased development in the Peace Athabasca drainage basins (oil sands, pulp and paper mills, agriculture, urban areas, etc.) may potentially affect an increase in contaminant loading to Great Slave Lake. Because of this, it is of vital importance that a long-term monitoring program be established to assess the changing condition of contaminants in the Great Slave Lake ecosystem. An even larger long-term data set for POPs and metal concentrations exists for the Slave River (Sanderson et al. 1997, McCarthy et al. 1997). Fish samples and/or sample extracts are archived from these collections. The addition of a Slave River site to our monitoring program in 2000 will help to assess whether or not contaminant concentrations in burbot in the river are decreasing.

Third, studies conducted in the early 1990s as part of the Northern River Basins Study (Pastershank and Muir 1996) showed elevated concentrations of PCBs in burbot liver along several reaches of the Peace and Athabasca rivers. Levels approached or exceeded those observed in the Slave River and Great Slave Lake. These higher concentrations may have been related to trophic feeding and/or to local PCB inputs. The Northern Rivers Ecosystem Initiative is supporting research to elucidate these issues, including possible declines in contaminant body burdens in burbot in Peace and Athabasca River systems. Our monitoring study, especially in the Slave River and Fort Resolution area, will allow for a further assessment of the contaminant status of the Peace and Athabasca Rivers including how changing contaminant trends may affect the Great Slave Lake ecosystem.

Fourth, Great Slave Lake is a major population centre in the Northwest Territories. Yellowknife is the territorial capital while Hay River is an important transportation hub with road and rail links to the south, and is a port serving the Mackenzie River, the outflow from Great Slave Lake. Fort Resolution and Lutsel K'e are two major communities located on the Great Slave Lake shoreline that make extensive use of its fish populations. Both communities are concerned about contaminant concentrations in their fish and have supported other and our NCP studies for many years. Fort Smith also is concerned about contaminant concentrations in fish in the Slave River.

Fifth, in contrast to most aquatic systems in the Northwest Territories, the Great Slave Lake is well-studied with the major features of its limnology and fisheries ecology well understood. Classic limnological and fisheries studies were conducted by Rawson (1950, 1951, 1953, 1956). More modern research studies include Fee et al. (1985), Patalas and Patalas (1978) and Evans et al. (1996, 1998).

Sixth, the Great Slave Lake commercial fishery has been in existence since the early 1950s. It is a highly regulated fishery with fishing quotas established for some areas of the lake while other areas are closed to commercial fishing. While long-term records have been maintained on the Great Slave Lake fisheries, few studies have investigated contaminant concentrations in the fisheries. In contrast, there are extensive long-term data sets for contaminant trends in Great Lakes fish (Hesselberg et al. 1990, Suns et al. 1993, Huestis et al. 1996). Thus it is timely that similar such data sets are beginning to be generated for important Great Slave Lake fish.

Activities 2000-2001

The Great Slave Lake long-term biomonitoring program began in 1999 with the collection of pike, lake trout and burbot at Lutsel K'e and at Fort Resolution. In the West Basin, lake trout were collected near Slave Point at the lake outflow. In 2000, the same species were collected in the same general locations although lake trout were collected in the Simpson Island region, which is much closer to the Slave River plume. In February 2001, burbot were collected in the Slave River, near Fort Smith.

Intact fish were shipped to DFO (Burlington) for initial examination (final length determinations, sex, % moisture, % lipid), tissue preparation and extraction. Some of this work is ongoing for fish caught in 2000-2001. Most of the analyses for the fish caught in 1999-2000 have been completed while analyses of fish caught in 2000-2001 continue. Burbot liver and lake trout and pike muscle are being analyzed for POPs including PCBs, DDT, dieldrin and toxaphene. A subset also is being examined for coplanar PCBs and being prepared for possible future dioxin/furan analyses. Muscle is also being analyzed for metals (Hg, arsenic and selenium), and carbon and nitrogen isotope analyses. The latter analyses may provide information on carbon sources and trophic feeding.

Following the removal of the appropriate tissues from the individual fish, the remaining fish samples are homogenized and homegenates placed in several 500-mL containers for archiving. These samples are shipped back to NWRI (Saskatoon). Because relatively small amounts of tissue were removed from most fish (the exception is the smaller burbot from Lutsel K'e), these homogenates represent "whole body." At some later date, we could compare contaminant determinations on tissue samples (of interest from a consumption viewpoint) and whole body (of interest in the biomagnification of contaminants from one organism to another).

Results and Discussion

Fish collected from different regions of Great Slave Lake in the 2000-2001 study year were similar in mean length and weight (Table 1). Lake trout from Lutsel K'e and the Simpson Islands were particularly similar in size. Burbot caught from Resolution Bay were larger than burbot caught from Lutsel K'e, as was observed in 1999-2000 (Evans and Muir 2000). Fort Smith burbot were intermediate in size to burbot caught from the two locations in Great Slave Lake. Lake trout and burbot were similar in size in 1999-2000 and 2000-2001; somewhat larger pike were collected at Lutsel K'e in 2000 than in 1999 (666 ± 158 mm). The Fort Resolution pike and burbot populations were strongly dominated by males. This was not observed in 1999.

Stable isotope analyses have been completed for fish collected in 1999-2000. These data are shown (Table 2), along with data collected in earlier years. Lipid data are based on muscle except for burbot where it is based on

Table 1. Summary statistics for fish (n = 10) caught in Great Slave Lake and the Slave River, 2000-2001

Fish	Location	Time	% Females	Length (mm)	Weight (g)
East Arm					
Lake trout	Lutsel K'e	Summer	40	616 ± 54	2178 ± 435
Pike	Lutsel K'e	Summer	80	737 ± 166	2865 ± 1,551
Burbot	Lutsel K'e	Summer	40	479 ± 33	882 ± 333
West Basin					
Lake Trout	Simpson Islands	Summer	80	655 ± 3	2834 ± 550
Pike	Resolution Bay	Summer	20	654 ± 90	2156 ± 914
Burbot	Resolution Bay	Summer	20	648 ± 84	2354 ± 654
Slave River					
Burbot	Fort Smith	Winter	n. d.[1]	571 ± 54	1326 ± 574

[1] Not determined

Table 2. Summary statistics for % lipid, ^{13}C and ^{15}N in muscle of fish collected in 1999-2000

Fish	Year	% Lipid	^{13}C‰	^{15}N‰
East Arm				
Lake trout	1993	7.6 ± 3.9	-31.9 ± 1.3	11.6 ± 0.3
Lake trout	1995	16.0 ± 9.6	-29.3 ± 1.2	12.3 ± 0.2
Lake trout	1999	5.2 ± 3.5	-27.9 ± 5.2	11.2 ± 0.8
Pike	1999	1.0 ± 0.7	-24.7 ± 1.5	10.8 ± 0.5
Burbot[1]	1993	30.0 ± 7.9	-24.8 ± 1.3	11.4 ± 0.2
Burbot[1]	1999	28.7 ± 6.0	-23.4 ± 1.9	10.8 ± 0.9
West Basin				
Lake Trout	1993	12.8 ± 3.1	-30.2 ± 0.7	12.5 ± 1.4
Lake Trout	1999	7.9 ± 1.6	-30.3 ± 1.4	12.4 ± 0.4
Pike	1996	2.2 ± 0.6	-28.6 ± 0.4	12.2 ± 0.2
Pike	1999	0.9 ± 0.3	-28.1 ± 1.0	11.1 ± 0.5
Burbot[1]	1993	22.8 ± 8.9	-29.2 ± 0.2	11.7 ± 0.3
Burbot[1]	1995	21.2 ± 13.7	-26.1 ± 1.9	11.0 ± 0.9
Burbot[1]	1996	43.3 ± 9.2	-29.0 ± 0.5	12.3 ± 1.1
Burbot[1]	1999	35.4 ± 8.1	-26.7 ± 6.5	12.1 ± 0.6

[1] Lipid analyses were based on liver.

liver. Lipid values in lake trout from Lutsel K'e varied markedly between the three collection periods with highest values in fish caught in 1995. Lake trout had somewhat higher ^{15}N in 1995. Lake trout from the West Basin tended to have higher % lipid and ^{15}N values than the East Arm lake trout for the 1999 collections year, suggesting a richer diet more strongly dominated by fish. Rawson (1951) reported that lake trout from the West Basin consumed proportionately more fish than lake trout from the East Arm. ^{13}C values were also higher for West Basin lake trout suggesting closer trophic links with plankton rather than periphyton. Burbot tended to have even greater differences in ^{13}C values between the East Arm and West Basin and somewhat higher ^{15}N values. Lipid concentration in burbot liver varied between in the West Basin but was less variable in the East Arm. Pike had the lowest lipid muscle content. Both ^{15}N and ^{13}C values tended to be higher for pike from the West Basin than the East Arm.

Analyses of samples collected in 1999 for metals have been completed (Table 3). These data can be compared to the limited metals data from earlier sampling in Great Slave Lake. Highest Hg concentrations were found in pike muscle, although mean concentrations were well below the 0.5 $\mu g \cdot g^{-1}$ guideline for the commercial sale of fish. Mercury concentrations also were lower than in many of the smaller lakes investigated by Lockhart et al. (2000) north of Great Slave Lake, although similar to concentrations observed in Belot and Colville Lakes, which are relatively large lakes located north of Great Bear Lake. The lowest Hg concentrations in the Great Slave Lake fish sampled in 1999-2000 were in burbot. Arsenic concentrations were highest in lake trout muscle. Selenium concentrations were slightly higher and somewhat more variable in the East Arm than West Basin fish. No time trends were evident from these limited data sets. A stronger data set for investigating time trends in Hg will be obtained once the burbot caught from the Slave River in 2000 are analyzed since burbot were sampled over a greater number of years during the Slave River Study and metal analyses were routinely run. The Great Slave Lake metals data will be added to the data sets for our project investigating the factors affecting elevated Hg levels in predatory fish in the Mackenzie River Basin.

Table 3. Metals concentrations (μg·g^{-1} wet weight) in muscle of fish collected in 1999 and comparisons with historical data

Fish	Year	Hg	Se	As
East Arm				
Lake trout	1995	0.13 ± 0.06	—	0.22 ± 0.05
Lake trout	1999	0.14 ± 0.52	0.29 ± 0.10	0.28 ± 0.12
Pike	1999	0.20 ± 0.14	0.35 ± 0.10	0.10 ± 0.03
Burbot	1999	0.08 ± 0.04	0.31 ± 0.06	0.13 ± 0.05
West Basin				
Lake Trout	1999	0.11 ± 0.02	0.29 ± 0.02	0.21 ± 0.07
Pike	1996	0.25 ± 0.02	—	0.15 ± 0.04
Pike	1999	0.24 ± 0.10	0.25 ± 0.02	0.16 ± 0.05
Burbot	1995	0.09 ± 0.04	—	0.11 ± 0.05
Burbot	1996	0.08 ± 0.05	—	0.13 ± 0.05
Burbot	1999	0.11 ± 0.03	0.23 ± 0.03	0.12 ± 0.02

Organochlorine analyses have been completed on fish collected in 1999. Lake trout and pike muscle and burbot liver are being analyzed for a wide variety of POPs. These data have been received recently and so the full interpretation of the data is ongoing. In brief, the initial observations are as follows.

First, in earlier research, we noted that OC contaminants tended to occur in higher concentrations in fish (and invertebrates) collected from the East Arm (Lutsel K'e region) than the West Basin (Fort Resolution region). However, with the 1999 data, we are observing the converse trend (Figures 1 and 2); higher concentrations of dieldrin, chlordane, DDT (burbot only), PCBs and toxaphene were found in lake trout and burbot collected from the West Basin rather than the East Arm. The reasons for these differences are unclear. While % lipid and ^{15}N was slightly higher in the West Basin versus the East Arm fish in 1999, this also was observed over the period 1993 to 1996.

Second, dieldrin, chlordane, DDT, PCBs and toxaphene data are suggestive of a trend of declining concentrations in the Lutsel K'e region between 1993 and 1999. This trend also is evident for burbot liver collected from Lutsel K'e. Such differences do not appear to be lipid-related for lake trout nor to trophic feeding. Age data have not yet been received and so further comparisons based on age will be made at a later date. With a relatively small number of years of study, it is difficult to be certain that there is a real trend in the data. However, because other monitoring programs are in place in other lakes in the Northwest Territories and the Yukon, these evaluations can be strengthened as more of the studies report their results.

There is no evidence of a decline in POPs concentrations for lake trout collected from the West Basin (Figure 1). POPs concentrations are consistently higher in 1999 than in 1993 although % lipid values are lower. There is a larger data set for burbot liver from the West Basin. Concentrations are similar to those observed in earlier years and no time trend is evident for any compound. Again, the analyses of these data will continue to investigate the reasons for similar POPs concentrations in 1993 when compared to earlier years of collection.

PCB data for burbot collected in 1993 and 1999 from the West Basin and the East Arm were examined to investigate possible temporal and spatial differences in homologue concentration and composition. For East Arm burbot liver, concentrations (and % composition) of penta- and hexa-PCBs were lower in 1993 than 1999 while slightly higher concentrations of mono/di-PCBs were observed (Table 4). Burbot liver from the West Basin in 1993 was similar in homologue composition to burbot liver from the East Arm in 1993, although PCB concentrations were lower. However, in 1999, West Basin burbot liver had a greater predominance of hexa- and hepta-PCBs and a lower predominance of mono/di-PCBs than burbot from the East Arm. Overall, burbot from the West Basin tended to have a high average PCB chlorine number than burbot from the East Arm both in 1993 (6.0 versus 5.5) and 1999 (4.5 versus 5.0).

Organochlorine contaminants occurred in higher concentrations in pike muscle collected from the West Basin than the East Arm in summer 1999 (Table 5). Lipid composition was similar between the two locations and so spatial differences do not appear to be directly related to lipids. Pike collected from the West Basin in 1996 had similar POPs concentrations to pike collected in 1999. Again, with only 2 years of observation, the detection of time trends is problematic.

There were a number of formal and informal communications over the last year of study. Informal communications involved telephone calls regarding sample collection and general questions. In March 2001, M. Evans visited Lutsel K'e and discussed the results of the previous and ongoing Great Slave Lake studies with a number of community representatives.

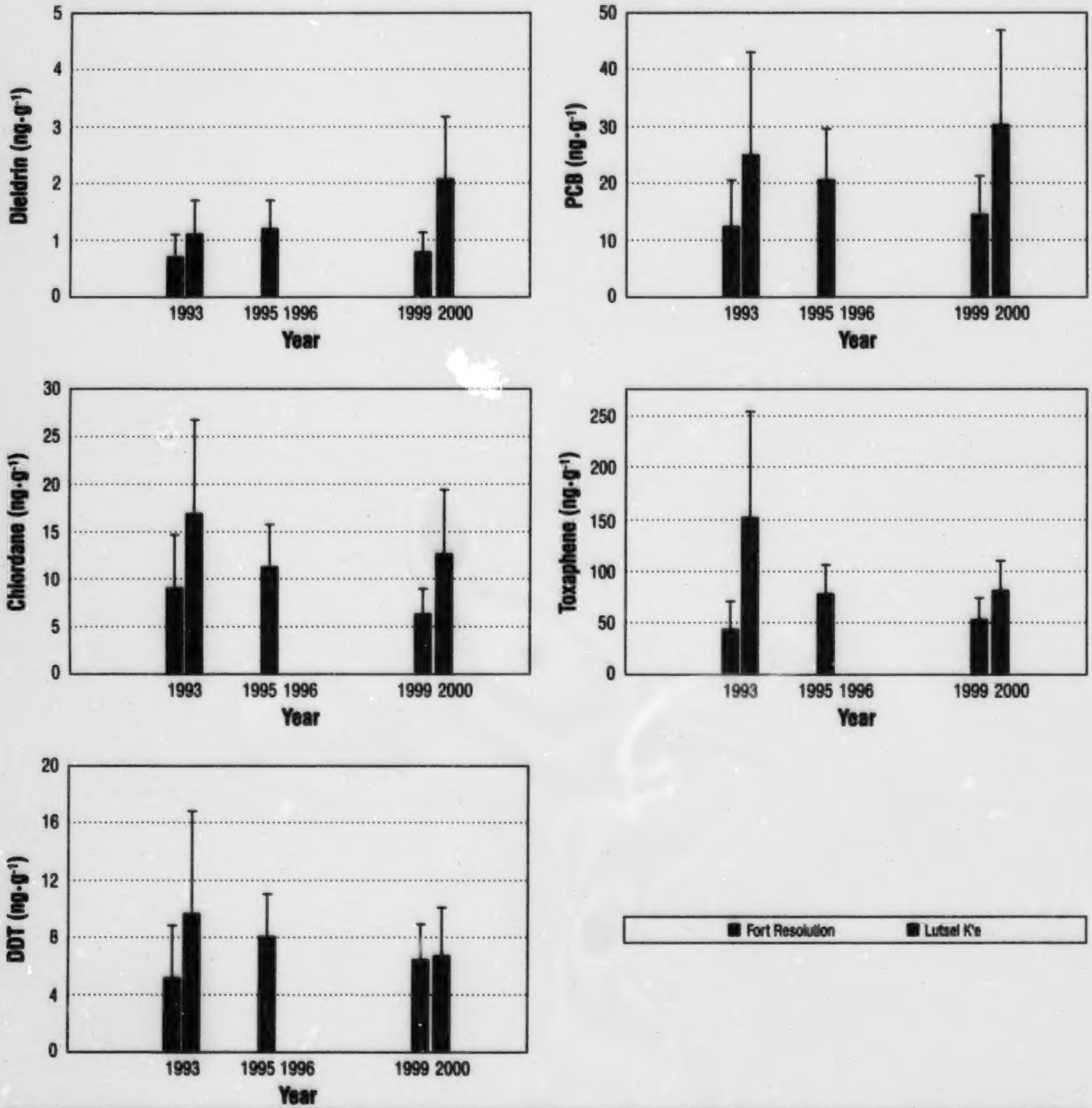
Data generated from the original Great Slave Lake study have been compiled into master data files and the majority of error checking completed. Fish data from the 1999-2000 sampling season will be placed into a brief report that will summarize these earlier data and contaminant data from the 1999-2000 studies. In addition, comparisons will be provided with contaminant levels in similar fish from the Laurentian Great Lakes. By providing brief reports, we hope to streamline the rate at which contaminant data become available to the communities and for health assessments.

Conclusions

The second year of this study was successful, with pike, lake trout and burbot collected from the East Arm and West Basin of Great Slave Lake and burbot from the Slave River. Community support for these studies has been very good. As in 1999-2000, fish collected from the various sampling sites are similar to one another in length and weight. Burbot, however, appear to be more variable from location to location than the other two species.

The results of the metals studies have determined that Hg concentrations are relatively low in all three fish species, with highest values observed in pike. However, mean Hg concentration is well below the 0.5 $\mu g{\cdot}g^{-1}$ guideline for the commercial sale of fish. Organochlorine data have been received recently and the analyses of these data are ongoing. POPs concentrations are lower in lake trout

Figure 1. Organochlorine contaminants in lake trout muscle, Great Slave Lake



muscle and burbot liver from the East Arm in 1999 than in 1993, but the data sets are relatively small for inferring time trends. In contrast, POPs concentrations in fish collected in the West Basin are similar to concentrations observed in earlier years.

Further analyses, including adjustments for lipid content, fish age, etc. may help explain these spatial and temporal differences. In addition, comparison of our results with the results of studies at other ongoing NCP monitoring studies will help to resolve what time trends are occurring. The results of this study and early studies are of interest to the communities and communications are good. The publication of a brief report summarizing the major features of the fish data will improve these communications and help streamline the consumption assessments.

Expected Project Completion Date

This is an ongoing monitoring study. Annual sampling is projected until winter 2002 and analysis of collected fish until 2003. It is further anticipated that monitoring will continue after NCP Phase 2 is completed.

Figure 2. Organochlorine contaminants in burbot liver, Great Slave Lake

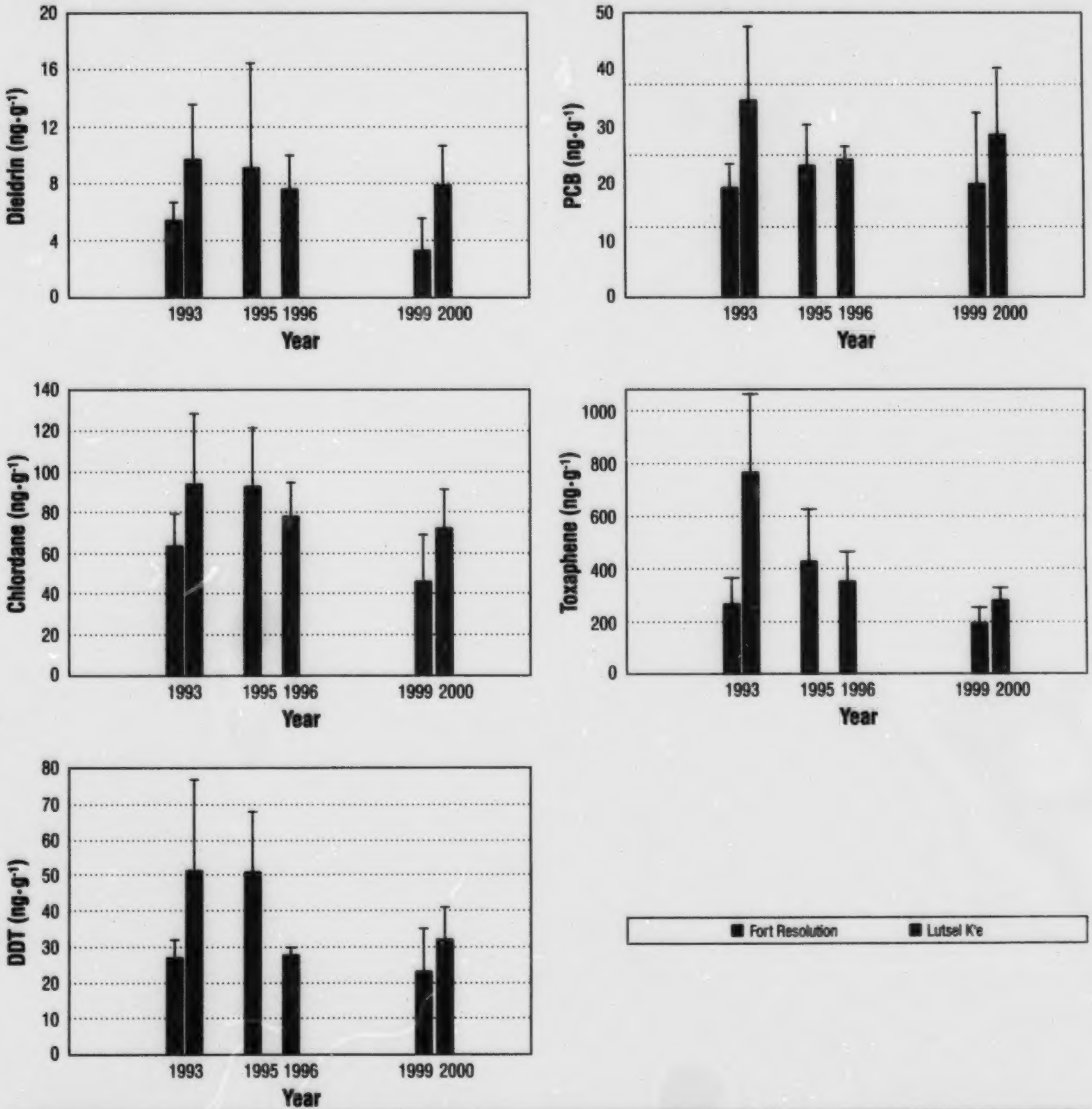


Table 4. Mean PCB homologue concentration (± standard deviation) and percent composition in burbot liver for fish caught in 1993 and 1999 in the West Basin and East Arm

	West Basin				East Arm			
	1993		1999		1993		1999	
	$ng \cdot g^{-1}$	% Composition	$ng \cdot g^{-1}$	% Composition	$ng \cdot g^{-1}$	% Composition	$ng \cdot g^{-1}$	% Composition
ΣMono/Di	0.5 (0.4)	0.7	5.9 (8.9)	5.2	0.0 (0.0)	0	10.9 (5.5)	13.7
ΣTri	2.8 (2.0)	3.6	5.4 (2.0)	4.7	4.3 (2.4)	3.2	4.1 (3.5)	5.2
ΣTetra	6.6 (2.5)	8.5	11.4 (6.1)	10	13.8 (9.5)	10.1	12.4 (8.4)	15.6
ΣPenta	21.4 (6.6)	27.7	22.3 (9.1)	20	45.4 (12.4)	33.2	16.0 (10.7)	20.2
ΣHexa	30.8 (5.9)	39.8	45.9 (17.1)	40.3	57.8 (20.7)	42.3	23.4 (15.5)	29.5
ΣHepta	11.5 (2.2)	14.9	20.5 (6.6)	18	14.0 (6.2)	10.3	10.9 (5.8)	13.7
ΣOcta	3.7 (2.2)	4.8	2.3 (1.2)	2	1.3 (1.0)	1	1.7 (1.0)	2.1
ΣNona	0.03 (0.08)	0.04	0.2 (0.5)	0.2	0.0 (0.0)	0	0	0
Total	**77.3**	**100**	**113.9**	**100**	**136.6**	**100**	**79.4**	**100**

Table 5. Mean concentrations ($ng \cdot g^{-1}$ wet weight) (± standard deviation) of organochlorine contaminants in pike muscle from Great Slave Lake

Location	ΣDieldrin	ΣChlordane	ΣDDT	ΣPCB	ΣToxaphene
West Basin (1996)	0.16 ± 0.07	2.3 ± 0.7	2.7 ± 0.8	5.3 ± 1.5	19.3 ± 4.5
West Basin (1999)	0.20 ± 0.10	2.1 ± 1.0	2.6 ± 1.0	5.4 ± 2.4	23.9 ± 5.3
East Arm (1999)	0.12 ± 0.04	0.8 ± 0.2	1.22± 0.4	2.4 ± 0.8	11.7 ± 2.6

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Mercury in Fish from Stock Surveys of Lakes in the Western Northwest Territories: Investigations into the Factors Affecting Mercury Levels

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Abstract

Surveys of lakes from the Northwest Territories and Nunavut have consistently indicated that fish from these lakes often have muscle mercury levels above those recommended for human consumption. The questions arising from these observations relate to the geographic extent of the problem of high mercury levels, the sources of the mercury, whether the problem is entirely natural or whether there is an anthropogenic component, and whether the magnitude of the problem is changing. For several years, fish sampled in Northern Contaminants Program (NCP) projects have been analyzed for mercury. More recently fish taken in stock surveys carried out at the request of Renewable Resource Councils have also been analyzed. The result is a growing database of mercury in fish from lakes chosen either by other NCP projects or by local communities. The data reveals that different species generally contain different levels of mercury with predators such as lake trout, walleye and northern pike usually containing more mercury than forage feeders such as cisco and whitefish. Some of the levels in predators have been found to exceed levels considered safe for unrestricted consumption and a number of consumption advisories

have been issued. The reasons why levels of a given species are higher in one lake than another are not yet clear and are the subject of ongoing investigations.

Key Project Messages

1. Mercury (Hg) levels in muscle from whitefish and Arctic char are generally quite low and are thus safe to eat.
2. Top predator fish such as lake trout, walleye and northern pike have the highest Hg concentrations. Mean levels were generally above or just below the Health Canada recommended limit for commercial sale.
3. Walleye had the highest recorded mean Hg concentrations of all fish species tested.

Objectives

1. Determine the occurrence and geographic distribution of Hg, selenium and arsenic in fish from those inland lakes in the Northwest Territories (NWT) being assessed by the Department of Fisheries and Oceans (DFO) their ability to produce sustained yields of fish for subsistence consumption by northern people.
2. Evaluate the levels of Hg found in the fish in terms of the age/size relationships of the fish and also in terms of the geological setting of each lake and its drainage, with a view to developing a management strategy for recommending levels of consumption based on species and size of fish on a lake-by-lake basis.

Introduction

Under the terms of land claims settlements, DFO is responsible for the conduct of studies on fish populations at the request of the Renewable Resource Councils in order to assess the existing or proposed harvest of stocks for subsistence, commercial or tourist uses. Historical DFO Inspection Service data indicate that muscle Hg levels in some of the larger fish from a number of lakes in the NWT exceed levels deemed safe by Health Canada for human consumption. However, the sample sizes are small and samples were generally biased to size classes typical of commercial catches.

Fish from a number of lakes have been surveyed over the past several years. The levels of Hg in the fish differ from lake to lake and conclusions drawn from one lake do not necessarily apply to another lake. Fish that feed near the base of the food chain (whitefish, cisco, sucker) consistently contain less Hg those that feed near the top of the food chain (walleye, pike, lake trout). In a number of instances, the predators contained levels high enough to require consumption advisories (Lockhart et al. 1999a, 1999b). We have begun to investigate the form of Hg found in the fish and results to date indicate that most of it is methylmercury.

Several factors can influence the level of Hg in fish tissues including fish age (or length), the structure of the supporting food chain, water chemistry, lake temperature, microbiological processes in the sediments, fish biochemistry, the supply of Hg to the lake and the nature of the drainage (e.g. rocks, uplands, wetlands, etc.). The supply of Hg is a mixture of natural geological contributions with human-related Hg appearing as additions to the natural supply. There is no doubt that gaseous Hg moves with air masses because concentrations in air have been measured at Alert (Schroeder et al. 1998) and further that Hg is found in snow falling in the Arctic (Lu et al. 2001). These studies, however, do not answer the question about the relative importance of natural and anthropogenic sources of Hg. To a surprising extent, the answer to this question remains unknown although lake sediment core studies suggest that, in some locations, anthropogenic inputs may be as large as natural inputs. While several Hg isotopes exist, the analytical precision necessary to discriminate among sources is not yet available.

Several independent lines of evidence suggest that Hg inputs to northern Canada have increased over pre-industrial levels. Mercury in Arctic seals and whales has increased since the 1970s (Wagemann et al. 1996). Sediment core data from a number of lakes in the NWT have suggested that recent Hg inputs are substantially above pre-industrial levels (Lockhart et al. 1998). Recently, Braune (1999) reported that Hg levels have also increased in seabirds. Given these considerations, it is important to assess Hg levels in stocks of fish being used now or being assessed for potential harvest in the near future.

Activities in 2000-2001

The most significant activity in 2000-2001 was the interpretation of some of the more recent data by Health Canada. Those interpretations have resulted in advice to the government of the NWT to have people limit consumption of fish from lakes indicated in Table 1. Significantly, all seven lakes – for which data were evaluated – included at least one advisory for restricted consumption. Different levels of consumption were advised for different individuals based on gender and age. Data from a number of other lakes have been evaluated and reported previously, while data from others have not yet been evaluated.

In addition, limited additional collections were made during 2000-2001 from Mirror and Bandy Lakes to supplement the data on hand from previous studies. The fish were analyzed according to methods originally described by Uthe et al. (1972). The analytical laboratory at the Freshwater Institute participated in internal and external quality assurance programs with good results.

Table 1. Recommended maximum weekly intakes of fish from Aubry, Belot, Colville, Deep, McEwen, McGill and Reade Lakes, NWT, based on Hg concentrations in white muscle[1]

Location	Species	RMWI[2] g·week^{-1} Adults	RMWI g·week^{-1} Women	RMWI g·week^{-1} Children
Aubry Lake	Lake whitefish	NC[3]	NC	NC
	Burbot	NC	NC	NC
	Lake trout	NC	NC	155
Belot Lake	Lake trout (1999)	NC	NC	185
	Burbot	NC	NC	285
Colville Lake	Lake whitefish	NC	NC	NC
	Lake trout	NC	NC	200
	Northern pike	NC	NC	150
	Burbot	NC	NC	NC
Deep Lake	Lake whitefish	NC	NC	150
	Northern pike	NC	125	55
	Walleye	180	75	35
	Cisco	NC	NC	140
McEwan Lake	Burbot	NC	NC	NC
	Cisco	NC	NC	NC
	Lake whitefish	NC	NC	NC
	Northern pike	NC	255	110
	Walleye	NC	235	105
McGill Lake	White sucker	NC	NC	180
	Walleye	175	75	35
	Northern pike	275	120	50
	Lake whitefish	NC	NC	245
	Burbot	NC	NC	NC
Reade Lake	Burbot	NC	NC	NC
	Lake whitefish	NC	NC	255
	Northern pike	NC	210	90

[1] Health Canada, February 2001

[2] Recommended maximum weekly intake

[3] Does not pose concern

Results and Discussion

Mirror Lake (64° 51′ N, 126° 55′ W)

In March 2000, 171 fish were obtained from Mirror Lake These consisted of one burbot, 63 lake trout and 107 lake whitefish. Muscle Hg levels were measured as in previous reports and the mean levels obtained are as shown in Table 2. These results are also shown graphically in Figure 1. The lake trout from this lake had relatively high levels and they also showed a distinct trend of increasing Hg with increasing fish size. The linear equation describing muscle Hg as a function of length was:

Muscle Hg ($\mu g \cdot g^{-1}$) = 0.00576 length (mm) – 2.044 ($r^2 = 0.67$).

The lake whitefish had lower mean Hg levels as expected, but there was no tendency for the larger fish to have higher Hg levels (Figure 1).

Bandy Lake (65° 16.083′ N, 126° 29.75′ W)

In April 2000, 19 Northern pike and 19 cisco were obtained from Bandy Lake. Mercury levels found are shown in Table 2. The results are also shown graphically in Figure 1. The northern pike showed a weak tendency toward higher Hg levels in larger fish, but the r^2 value was only 0.11. The equation generated describing Hg levels as a function of length was:

Muscle Hg ($\mu g \cdot g^{-1}$) = 0.000710 length (mm) – 0.096 ($r^2 = 0.114$).

Mercury levels in cisco were slightly lower and there was no indication of a trend with fish size.

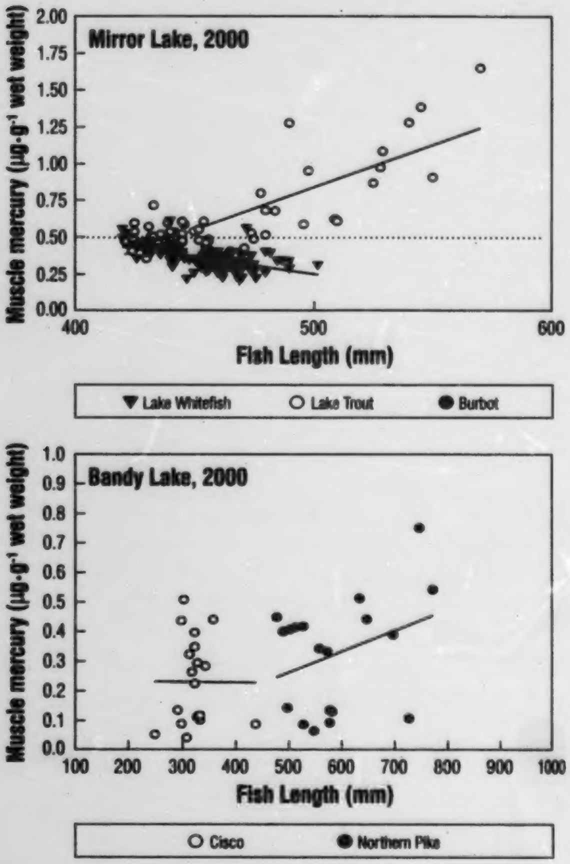
Comparisons among lakes

Since this is the final year for this survey project, it is appropriate to summarize the results to date. The data included in the summary are those from DFO accumulated since the 1970s, initially by the Inspection Service (now

Table 2. Mean mercury levels ($\mu g \cdot g^{-1}$) for fish obtained from Mirror Lake and Bandy Lake

Species	Mean Hg ($\mu g \cdot g^{-1}$) ± SD	Minimum	Maximum	N
Mirror Lake				
Burbot	0.397	—	—	1
Lake trout	0.606 ± 0.256	0.356	1.651	63
Lake whitefish	0.351 ± 0.071	0.212	0.616	107
Bandy Lake				
Northern pike	0.323 ± 0.192	0.063	0.751	19
Cisco	0.229 ± 0.149	0.040	0.507	19

Figure 1. Mercury ($\mu g \cdot g^{-1}$ wet wt) in muscle of fish from Mirror Lake (above) and Bandy Lake (below) as related to fish size (length)



part of the Canadian Food Inspection Agency), and more recently by this project. The comparisons are done in the form of maps (Figures 2 to 6) showing mean Hg levels in three ranges, namely:

Mean Hg < 0.2 $\mu g \cdot g^{-1}$ wet weight (light blue circles)
Mean Hg between 0.2 and 0.5 $\mu g \cdot g^{-1}$ wet weight (black circles)
Mean Hg > 0.5 $\mu g \cdot g^{-1}$ wet weight (dark blue circles)

These levels were selected for display purposes because they have been used to guide human consumption of fish. Fish with Hg > 0.5 $\mu g \cdot g^{-1}$ are prohibited from commercial sale in Canada. It has also been recommended that fish with Hg levels > 0.2 $\mu g \cdot g^{-1}$ not be consumed in subsistence fisheries, in which a lot of fish is eaten. It is recognized that better ways to calculate amounts suitable for consumption are available now, based on mean Hg level in the fish and acceptable daily intakes by fish consumers, but the earlier guideline levels are expressed more readily in map format.

Whitefish (lake whitefish and broad whitefish)

Data on Hg in whitefish muscle include results from 1922 fish taken from over 50 locations and are shown on the maps in Figure 2. The fish were all lake whitefish except for collections of broad whitefish from the Mackenzie River. The overall mean Hg level was only 0.101 $\mu g \cdot g^{-1}$. The smallest lake mean was 0.026 $\mu g \cdot g^{-1}$ while the highest was 0.285 $\mu g \cdot g^{-1}$. Of the locations sampled, none had a mean Hg level over 0.5 $\mu g \cdot g^{-1}$ and only four had mean Hg levels > 0.2 $\mu g \cdot g^{-1}$ (Deep, Thompson, a Jacques and Mirror Lakes) (Figure 2).

Northern pike

Six hundred and seventy-eight Northern pike from 37 collections have been analyzed and the data are shown in Figure 3. The overall mean for this species was 0.537 $\mu g \cdot g^{-1}$, just over the limit for commercial marketing in Canada. The range of means found was from 0.135 $\mu g \cdot g^{-1}$ to 1.749 $\mu g \cdot g^{-1}$. Only three mean values were < 0.2 $\mu g \cdot g^{-1}$ (Mackenzie River, one Great Slave collection and Hanson Lake in the Yukon). There were five other collections from Great Slave Lake and those all exceeded 0.2 $\mu g \cdot g^{-1}$. Collections from eleven locations exceeded 0.5 $\mu g \cdot g^{-1}$.

Lake trout

Data on 1685 lake trout from 71 collections are available. The mean Hg in muscle for all the lake trout was 0.480 $\mu g \cdot g^{-1}$, just under the limit for commercial marketing. The means from individual locations ranged from 0.072 $\mu g \cdot g^{-1}$ to 3.737 $\mu g \cdot g^{-1}$ (Giauque Lake, influenced by Discovery mine). Thirteen of the collections had mean muscle Hg values < 0.2 $\mu g \cdot g^{-1}$, 36 fell between 0.2 and 0.5 $\mu g \cdot g^{-1}$, and 22 were > 0.5 $\mu g \cdot g^{-1}$ (Figure 4).

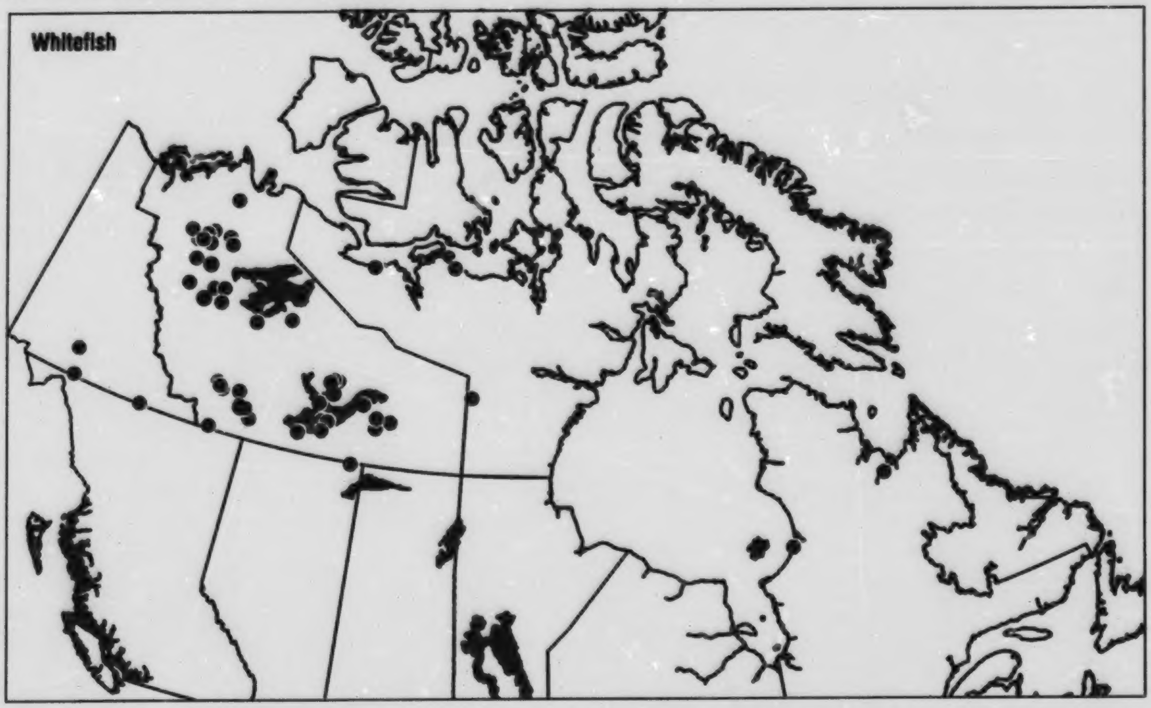
Walleye

We have fewer samples of walleye than of other species sought after for consumption or sale. The data describe 423 individual fish from 16 collections from 15 locations (Figure 5). The mean for all the fish was 0.602 $\mu g \cdot g^{-1}$, above limit for commercial sale and the highest recorded for any species. The means ranged from a low of 0.178 $\mu g \cdot g^{-1}$ for a collection from Great Slave Lake to a high of 1.299 $\mu g \cdot g^{-1}$ for one from Lac Ste. Therese. Only one mean fell below 0.2 $\mu g \cdot g^{-1}$. Almost half the means (7 of 16) exceeded the guideline of 0.5 $\mu g \cdot g^{-1}$ set for sale of commercial catches.

Arctic char

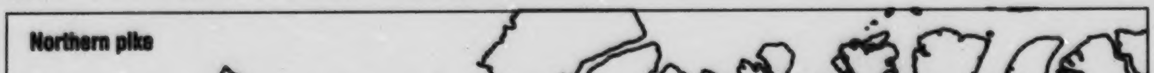
Data on Arctic char are relatively few because lakes in this study have been mostly in the southwestern NWT. However, some Hg data are available on char from earlier collections made as part of the previous biomarker project.

Figure 2. Levels of mercury in muscle of whitefish*



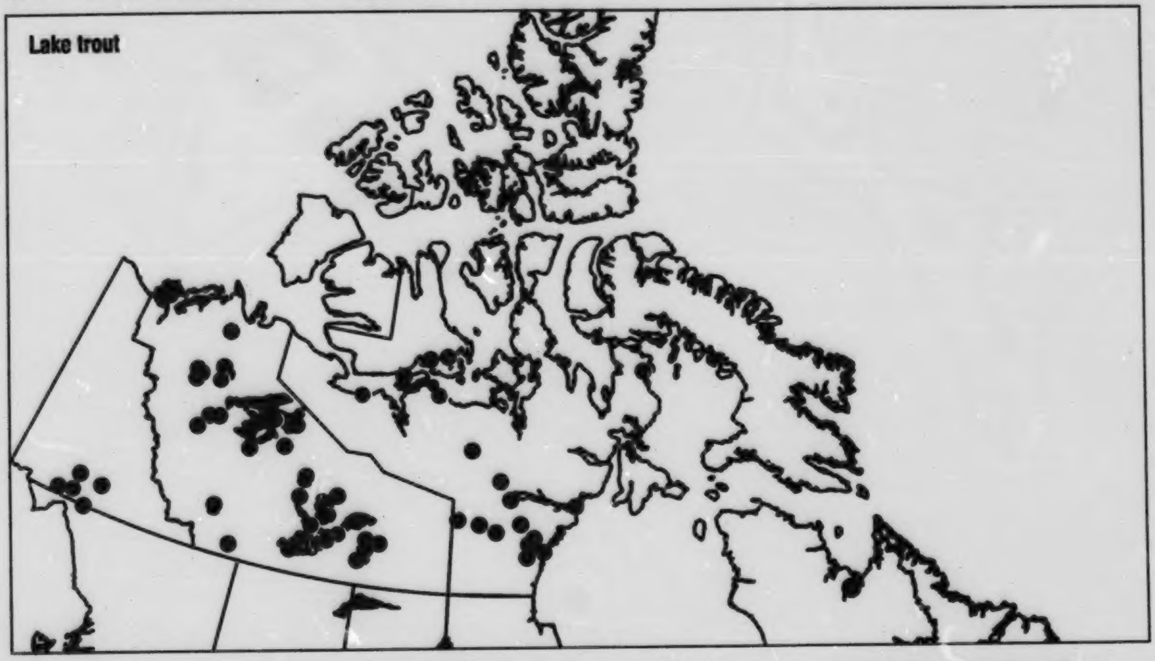
* Lakes with mean muscle mercury $< 0.2\ \mu g \cdot g^{-1}$ are shown in light blue circles; those with means $> 0.2\ \mu g \cdot g^{-1}$ but $< 0.5\ \mu g \cdot g^{-1}$ are shown as black circles. There were no cases where the mean mercury level in whitefish exceeded $0.5\ \mu g \cdot g^{-1}$.

Figure 3. Levels of mercury in muscle of northern pike*



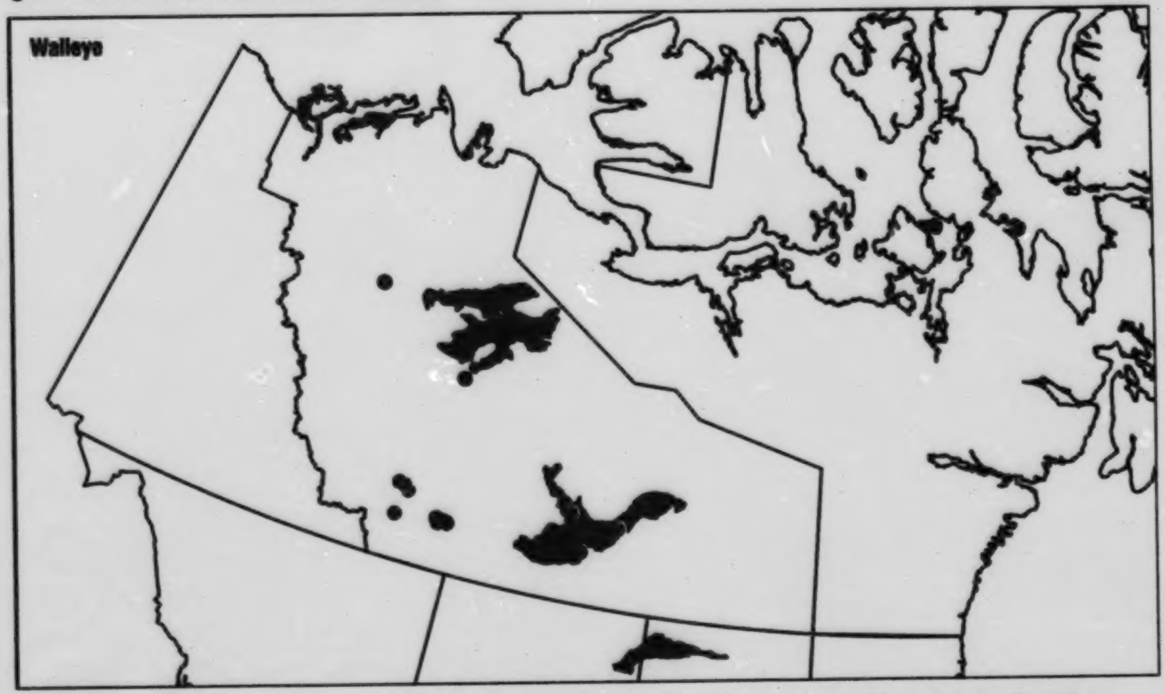
* Lakes with mean muscle mercury $< 0.2\ \mu g \cdot g^{-1}$ are shown in light blue circles; those with means $> 0.2\ \mu g \cdot g^{-1}$ but $< 0.5\ \mu g \cdot g^{-1}$ are shown as black circles. Those with mean mercury level in excess of $0.5\ \mu g \cdot g^{-1}$ are shown as dark blue circles.

Figure 4. Levels of mercury in muscle of lake trout*



* Lakes with mean muscle mercury < 0.2 μg·g⁻¹ are shown in light blue circles; those with means > 0.2 μg·g⁻¹ but < 0.5 μg·g⁻¹ are shown as black circles. Those with mean mercury level in excess of 0.5 μg·g⁻¹ are shown as dark blue circles.

Figure 5. Levels of mercury in muscle of walleye*



* Lakes with mean muscle mercury < 0.2 μg·g⁻¹ are shown in light blue circles; those with means > 0.2 μg·g⁻¹ but < 0.5 μg·g⁻¹ are shown as black circles. Those with mean mercury level in excess of 0.5 μg·g⁻¹ are shown as dark blue circles.

The char data are mostly from the Inspection Service and usually involve very small numbers of samples. We have data on 336 char from 26 locations (Figure 6). The mean Hg level for all the fish was 0.082 $\mu g \cdot g^{-1}$, with a range from 0.014 (Tessikakjuak Lake, n = 5) to 0.698 $\mu g \cdot g^{-1}$ (Amituk Lake). Only one mean exceeded 0.5 $\mu g \cdot g^{-1}$ (Amituk Lake) and only one fell between 0.2 and 0.5 $\mu g \cdot g^{-1}$ (Sophia Lake, n = 3).

Conclusions

The problem with Hg in fish from lakes in northern Canada is relatively specific to predator species like walleye, northern pike and lake trout. Species that feed lower in the food chain like lake whitefish have low levels of Hg. Arctic char generally have low levels of Hg also, notably anadromous populations; some collections of char had high levels, probably as a result of non-migratory habits. The problem with predator species is extensive geographically; fish from the Yukon to northern Nunavut have been found to contain high levels of Hg. Lake trout from Nunavut had an unusually high proportion of means over the limit for marketing.

The data on hand generally do not lend themselves well to the question of temporal change since sample numbers were often small, particularly for early collections made for Inspection Service purposes. This project has produced the first relatively large samples from NWT and Nunavut lakes. These will facilitate the identification of temporal trends with high statistical rigour in future studies.

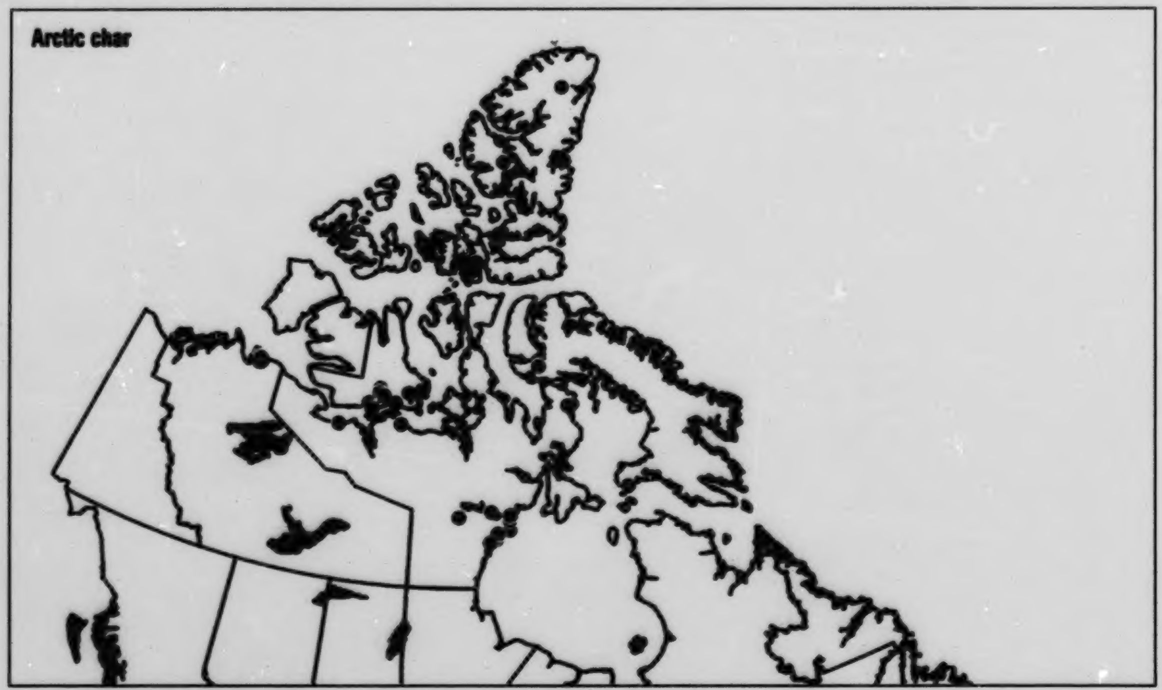
Expected Project Completion Date

This project is being terminated. The only activities remaining are to present the data at the International Conference on Mercury as a Global Pollutant in Japan in the fall 2001 and to submit a manuscript for publication as part of the conference journal issue.

Acknowledgments

Data from the DFO Inspection Service (now part of the Canadian Food Inspection Agency) were furnished by Marilyn Hendzel and Pat Jones.

Figure 6. Levels of mercury in muscle of Arctic char*



* Lakes with mean muscle mercury < 0.2 $\mu g \cdot g^{-1}$ are shown in light blue circles; those with means > 0.2 $\mu g \cdot g^{-1}$ but < 0.5 $\mu g \cdot g^{-1}$ are shown as black circles. Those with mean mercury level in excess of 0.5 $\mu g \cdot g^{-1}$ are shown as dark blue circles.

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Temporal Trends of Persistent Organic Pollutants and Metals in Landlocked Char

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Abstract

This study is examining temporal trends of persistent organic pollutants and metals, especially mercury, in landlocked Arctic char from lakes near the community of Qausuittuq (Resolute) by analysis of annual sample collections. This is the second report on this study. There has been no statistically significant change in mercury concentrations in char from Resolute Lake over the 8-year period. However, mean concentrations in char from 1999 and 2000 in Resolute Lake were 15% to 20% lower than those from 1992 and 1997. If a slow decline is occurring, it will take additional annual sampling to confirm this. Polychlorinated biphenyl (PCB) levels in char from Resolute Lake in 1997 were higher than those in 1999, after adjusting for length. Further sampling and analysis will be needed to determine if this observation is part of a declining trend of PCB inputs. Levels of PCBs and DDT-related compounds were much lower in char from Char Lake in 1999 and 2000, compared with results from char collected in nearby Char Lake in 1993; this is probably because only piscivorous char from 1993 were analyzed. In Resolute Lake, both mercury and ΣPCBs were significantly correlated with $\delta^{15}N$ in char collected in 1997 and 1999. This suggests that biomagnification of mercury and organochlorines is occurring within the char population due to the presence of piscivorous char. Support for presence of piscivory comes from the differences of up to 3.8 parts per thousand in $\delta^{15}N$ found in char from Resolute Lake.

Key Project Messages

1. No significant decline in mercury (Hg) concentrations was detected in Arctic char from Resolute Lake from 1992 to 2000, although mean concentrations in 2000 are 20% lower than those from 1992 and 1997.

2. PCB levels in char from Resolute Lake in 1997 were higher than those in 1999, after adjusting for length, but further sampling is needed to confirm whether this is a long-term trend.
3. Results for nitrogen stable isotope ratios show that some char in Resolute Lake are piscivorous and are accumulating higher levels of PCBs and Hg due to biomagnification.

Objectives

1. Determine temporal trends of persistent organic pollutants (POPs) and metals, especially Hg, in landlocked Arctic char in lakes near Qausuittuq (Resolute) by analysis of annual sample collections.
2. Investigate factors influencing contaminant levels in landlocked char, such as the influence of sampling time, water temperature, and diet.
3. Provide this information on a timely basis to the community of Qausuittuq (Resolute).

Introduction

Freshwater organisms are exposed to atmospheric contaminants deposited on snow or directly onto lake surfaces or lake watersheds. Fish accumulate contaminants, metals and organometallics as they pass water over their gills as well as from their diet. It has been shown that rising water temperatures lead to increased metabolic rates and thus pumping of higher volumes of water across the gills, which in turn results in increased uptake of metals from the water. Unlike mammals, fish have limited capacity to degrade most POPs and metals, and excrete many of these chemicals very slowly. Fish are, therefore, good indicators of freshwater contamination by POPs and metals.

Small lakes in the high Arctic are replenished annually with snowmelt runoff and direct precipitation, which represent significant fractions of their water budgets. Declining concentrations of POPs, or increasing levels of previously unstudied POPs, in air and precipitation should be reflected relatively quickly in changes in levels in food webs and top predator fishes, compared to the vast marine environment. We know this to be the case from the sedimentary record of POPs and Hg in small Arctic lakes (Muir et al. 1996, Lockhart et al. 1998).

The value of long-term annual sampling of fish for measurement of temporal trends of contaminants was well illustrated by studies in Sweden. Arctic char have been collected since 1980 in Lake Abiskojaure, 200 km north of the Arctic Circle, and northern pike have been collected from Lake Storvindeln, a forest lake in northern Sweden, since 1978. Samples were collected annually and were selected for consistency in sex, age, size and sampling season. Each annual sample at a given location was represented by 10 to 25 specimens, thus within-year variation could be estimated. Declines in levels of ΣDDT (DDT + DDD + DDE), PCBs and hexachlorobenzene (HCBz) were noted in fish from the Arctic locations (Olsson and Reutergårdh 1986, DeMarch et al. 1998). The Arctic char data provided a more accurate temporal trend than pike muscle because char has a higher concentration of fat. Hexachlorocyclohexane (HCH) isomers showed no significant declines in fish muscle over a 24-year period. Because of annual sampling, the Swedish program was also able to detect increases in DDT inputs due to the use of DDT in East Germany in 1984 (Bignert et al. 1993).

Lakes near Qausuittuq (Resolute) are ideal sites for a study of temporal trends of POPs and metals in fishes. Many of the lakes (e.g. Char, Resolute, Meretta) are well studied limnologically and the food chain in Char Lake has been well documented (Hobson and Welch 1995). Char from Char Lake collected by H. Welch in 1993 have been previously analyzed for organochlorine contaminants and metals (Muir and Lockhart 1996, Muir et al. 1997). Levels of PCBs and total DDT in char muscle (plus skin) were relatively high compared to other landlocked or sea run char (Muir et al. 1997). Other persistent organochlorines (e.g. chlordane, toxaphene) in Char Lake char were at levels similar to other Canadian Arctic locations. The higher levels of DDT and PCBs may represent local contamination but could also be due to trophic position of the char that were sampled.

The assessment of contaminants conducted by the Northern Contaminants Program (NCP) (Jensen et al. 1997, Muir et al. 1997) found that there was limited information on temporal trends in fish, especially in the eastern and high Arctic. This study is designed to help fill that knowledge gap.

Activities in 2000-2001

Sample collection

Arctic char were collected from Char and Resolute lakes in August 2000 by Dr. Köck and research team, working with Debbie Iqaluk of Qausuittuq, using either hand methods or gill netting; char were also collected from North Lake (about 10 km northwest of Qausuittuq). These added to previous collections of landlocked char from Resolute Lake (1997, 1998, 1999), Char Lake (1999), Boomerang Lake on Somerset Island (1999) and Sapphire Lake on Devon Island (1999). Samples (skin on fillets) were frozen in Resolute, shipped to NWRI (Burlington) and stored at

–20°C until analysis. Subsamples were also shipped to J. Reist (DFO, Winnipeg). Aging of the char was done by J. Babaluk (DFO, Winnipeg).

Chemical analysis

Metals

Arctic char muscle was subsampled and acid-digested using high pressure microwave. The digest was then analyzed for Hg by cold vapour atomic absorption spectrometry and for 22 elements using inductively coupled plasma-low resolution mass spectrometry.

Organochlorines

Char (muscle plus skin) samples were homogenized, mixed with pre-cleaned Na_2SO_4 and Soxhlet extracted with dichloromethane:hexane (1:1). Organochlorines were isolated by gel permeation chromatography, followed by silica gel clean-up. The chromatography on silica gel was used to separate PCBs and *p,p'*-DDE from more chlordane and toxaphene components, *p,p'*-DDT and HCH isomers. The two fractions from the silica gel column were then analyzed by gas chromatography with electron-capture detection. Separation was accomplished on a HP 6890 GC using a 30 m DB-5 column with H_2 carrier gas. ΣPCBs represented the sum of 103 congeners. Toxaphene was analyzed by low resolution GC-negative ion MS using a HP 5973 MSD in negative ion mode.

Quality assurance

Quality assurance steps included the analysis of certified reference materials for heavy metals and organochlorines, reagent blanks and duplicate samples. The National Laboratory for Environmental Testing (NLET) organics and metals labs are participants in the NCP Quality Assurance Program. The NLET organics lab is a participant in the Quality Assurance for Marine Environmental Monitoring in Europe (QUASIMEME) programs for PCBs and toxaphene. NLET is certified by the Canadian Environmental Analytical Laboratory program of the Canadian Standards Association.

Statistical analyses

Mean concentrations of metals and organochlorines in char from Resolute Lake were compared among years using the General Linear Models procedure in Systat (Ver 9) (SPSS 1999). The analysis of covariance (ANCOVA) model included year, sex and length, and their interactions. Results were first tested for normality using skewness and kurtosis tests. Length adjusted least square means from the ANCOVA were calculated and compared using Tukey's (Post-hoc) Test.

Results and Discussion

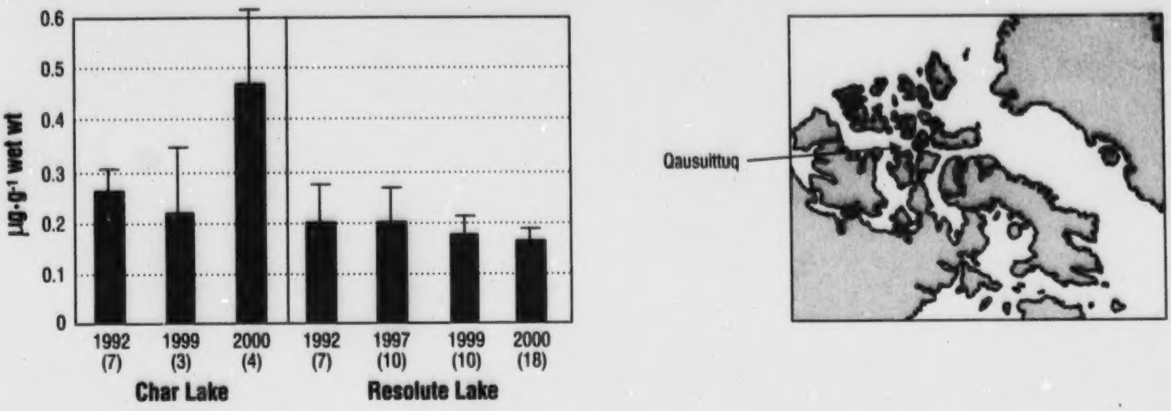
Concentrations of Hg ($\mu g \cdot g^{-1}$ wet weight) and other elements in landlocked Arctic char from Resolute, Char and North Lakes are shown in Table 1. Statistical analysis showed that concentrations of Hg and most other elements in char muscle from Resolute and North lakes were normally distributed. Mercury concentrations in char from Resolute Lake in 2000 were about 20% lower than those from 1992 and 1997 (Figure 1). Further statistical analysis of the Resolute Lake data will be done when results from 2001 are available.

In the case of Char Lake, higher levels of Hg were found in samples from 2000 than from 1999. The limited number of char available from this lake makes comparison between years problematic. However, the char from 2000 were longer and heavier (37 ± 3 cm, 329 ± 80 g) compared to those from 1999 (28 ± 19cm, 201 ± 40g). The larger char from 2000 may have been feeding at a higher trophic level.

Table 1. Mean concentrations and standard deviation of mercury and other major elements ($\mu g \cdot g^{-1}$ wet wt) detected in muscle of landlocked Arctic char from lakes in the area of Qausuittuq (Resolute)

Lake	N		Length (cm)	Weight (g)	As	Cd	Cr	Ni	Pb	Rb	Tl	V	Se	Hg
Resolute	18	Mean	39	433	0.078	0.002	0.043	0.064	0.030	0.155	0.008	0.001	0.684	0.162
		SD	2	78	0.021	0.001	0.057	0.108	0.020	0.019	0.003	0.001	0.049	0.056
Char	4	Mean	37	329	0.098	0.002	0.056	0.028	0.021	0.147	0.009	0.001	0.725	0.550
		SD	3	80	0.022	0.001	0.063	0.022	0.010	0.026	0.003	0.000	0.074	0.271
North	14	Mean	36	382	0.063	0.002	0.005	0.024	0.026	0.108	0.004	0.002	0.374	0.202
		SD	6	143	0.033	0.001	0.013	0.041	0.036	0.038	0.002	0.001	0.044	0.115

Figure 1. Mercury in Arctic char from Resolute and Char Lakes, 1992-2000*



* Bars represent mean ± 95% confidence interval. Results from 1992 are from Muir and Lockhart 1996.

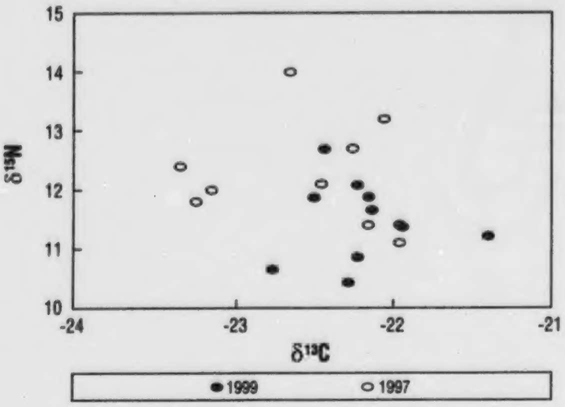
Results for persistent organochlorines measured in char from Resolute and Char lakes collected in 1997, 1999 and 2000 are shown in Table 2. PCBs were the major organochlorines present. Results for PCBs, ΣDDT and ΣCHL for Resolute Lake Arctic char were skewed, indicating that a few individual fish tended to have higher levels. Log transformation reduced skewness and transformed data were used to compare between years. Length adjusted PCB concentrations from 1997 were significantly higher than those from 1999. There were no differences between means for 1999 and 2000. The small numbers of char from Char Lake precluded any detailed statistical analysis. ΣPCB levels were lower in the four fish from 2000 compared to those collected in 1999.

The effect of diet and trophic level on Hg and organochlorine levels was investigated using stable isotopes of carbon and nitrogen (Figure 2). The char from Resolute Lake had a narrow range of $\delta^{13}C$, which indicates that they are feeding on similar diets. A few fish have $\delta^{15}N$ values that were up to 3.8 parts per thousand (‰) higher than others. Differences in $\delta^{15}N$ of this magnitude are associated with a change of trophic level because concentrations of the heavier isotope of nitrogen, ^{15}N, are progressively enriched from prey to predator an average of 3 to 5‰ (Peterson and Fry 1987). The $\delta^{15}N$ values suggests that these char were feeding one trophic level higher than others, probably on other char. Landlocked char populations are known to develop a behavioural dichotomy wherein some individuals at a certain "escape size" adapt to a cannibalistic feeding habit, while other individuals may not. In Char Lake, a system containing only char, Hobson and Welch (1995) associated $\delta^{15}N$ values of 13.7‰ with piscivory in char. They also found a significant increase in the $\delta^{15}N$ of these fish with size which they attributed to cannibalism within the population. There

Table 2. Mean concentrations and standard deviation of persistent organochlorines (ng·g⁻¹ wet wt) detected in landlocked Arctic char (whole fish) from Resolute and Char Lakes near Qausuittuq

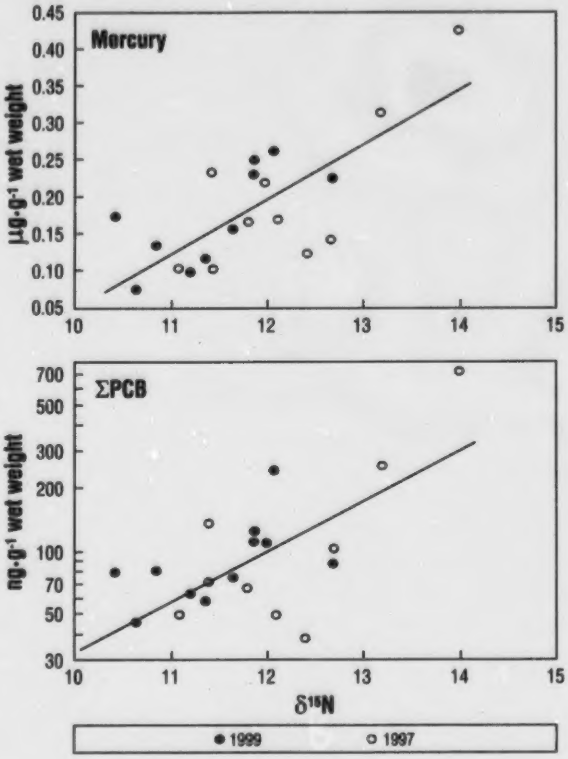
Lake	Year	N		% Lipid	Weight (g)	ΣPCB	ΣDDT	ΣCHL	ΣHCH	ΣCBz
Resolute	1997	10	Mean	5.2	33	160	9.2	6.8	0.68	1.7
			SD	2.8	3	208	13	8.9	0.58	1.6
Resolute	1999	10	Mean	3.8	40	97	6.7	4.7	0.70	1.5
			SD	1.3	3	57	3.3	2.3	0.28	0.41
Resolute	2000	8	Mean	5.5	40	133	8.8	1.7	0.70	2.1
			SD	1.5	1	69	4.8	0.66	0.18	0.56
Char	1999	3	Mean	2.9	28	125	32	1.0	0.33	1.1
			SD	1.8	9	48	8.3	0.40	0.17	0.55
Char	2000	4	Mean	2.8	37	65	15	2.1	0.46	1.0
			SD	0.4	3	31	9.3	0.75	0.07	0.05

Figure 2. Relationship of stable isotopes ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) in Arctic char muscle from Resolute Lake



* Differences in $\delta^{15}N$ of up to 3.8 indicate that some char are piscivorous.

Figure 3. Relationship of mercury and PCBs and $\delta^{15}N$ in landlocked Arctic char from Resolute Lake, 1997, 1999



* A significant relationship was found for both chemicals indicating that char with high PCBs and Hg are feeding at a higher trophic level.

were no significant correlations of $\delta^{15}N$ with length or weight in Resolute Lake char.

Both Hg and ΣPCB were significantly correlated with $\delta^{15}N$ in char from Resolute Lake collected in 1997 and 1999 (Figure 3). This trend, which was also observed for ΣDDT and ΣCHL but not for other metals or OC groups, suggests that biomagnification of Hg and organochlorines is occurring within the char population due to the presence of piscivorous char. These results support the hypothesis that the reason for higher levels seen in char sampled in 1993 in Char Lake (see Muir et al. 2000) was that piscivorous char were analyzed.

Conclusions

This is a long-term study of contaminant levels in landlocked Arctic char in the area of Qausuittuq. The results for Hg in char muscle from Resolute Lake suggest no significant change in concentrations of Hg over an 8-year period, 1992 to 2000. Mean concentrations in char from 1999 and 2000 in Resolute Lake were 15% to 20% lower than those from 1992 and 1997, however, if a slow decline is occurring it will take additional annual sampling to confirm this. Results also show that levels of Hg and metallic elements in landlocked char muscle in three other lakes (North, Sapphire, Boomerang) in the region are similar to those in Char and Resolute lakes. PCB levels in char from Resolute Lake in 1997 were higher than those in 1999 after adjusting for length. Further sampling and analysis will be needed to determine if this observation is part of a declining trend of PCB inputs. Levels of PCBs and DDT-related compounds were much lower in char from Char Lake in 1999 and 2000 compared with results from char collected in 1993. However, the sample sizes are very small and piscivorous char may have been selected for analysis in 1993. Since both PCBs and Hg have been shown to vary with trophic level of the char in Resolute Lake, stable isotope signatures of the fish will be important in helping to interpret temporal trends.

Expected Project Completion Date

This project is ongoing.

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Temporal Trends of Persistent Organic Pollutants and Metals in Ringed Seals from the Canadian Arctic

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Abstract

Temporal trends of mercury, PCBs, ΣDDT, β-HCH and γ-HCH in ringed seals were studied by comparing results from samples collected at Grise Fiord, Pangnirtung, and Pond Inlet with earlier published results. ΣDDT declined significantly in blubber of female seals from Grise Fiord from 1972-1993 but not from 1993-1998. Levels of ΣPCB10 (sum of 10 major congeners) were marginally higher in the 1972 samples than in those from 1993, but not significantly different from levels in samples from 1998. No statistically significant declines were found for ΣDDT or ΣPCB10 in ringed seals from Pangnirtung over the period 1985-1999. Arithmetic mean concentrations of mercury in adult ringed seals from Pond Inlet (2000) were three-fold higher than results reported by Smith and Armstrong (1978) for seals of the same average age. These are the first reports of temporal trends of persistent organochlorines and mercury in ringed seals from the eastern Arctic. In the case of DDT, results are similar to observations by Addison and Smith (1998) at Holman in the western Arctic. The increasing concentration of mercury observed at Pond Inlet is in accord with previous findings in the western Arctic from 1972-1993, based on a comparison of regression slopes (Wagemann et al. 1996) and observations by Braune (1999) of an approximately two-fold increase in mercury in thick billed murre eggs from Lancaster Sound over the period 1975-1998.

Key Project Messages

1. DDT levels declined in ringed seals at Grise Fiord while PCB levels showed few or no changes over a 26-year period (1972-1998). At Pangnirtung, DDT and PCBs showed no significant changes over the period 1985 to 1999.
2. β-HCH increased in ringed seals at both Grise Fiord and Pangnirtung while γ-HCH showed no major changes in concentration.
3. Mercury (Hg) levels increased three-fold in ringed seal liver at Pond Inlet over a 24-year period (1976-2000), which is in accord with previous findings for seals in the western Arctic and for seabirds.

Objectives

1. Determine temporal trends of persistent organic pollutants (POPs) and Hg in ringed seals and walrus from locations previously studied in the 1980s and early 1990s.
2. Provide information on levels and temporal trends of these contaminants to each community participating in the study on a timely basis.

Introduction

The ringed seal is the most abundant Arctic pinniped with a circumpolar distribution, making this species an ideal candidate for examining spatial trends of persistent organic pollutants (POPs) in the Arctic. It is identified as a key species for monitoring by the Arctic Monitoring and Assessment Programme and for temporal trends monitoring by the Northern Contaminants Program (NCP 1999). As a top predator in near-shore pelagic food webs, the ringed seal prefers land-fast ice or multi-year ice. The ringed seal diet consists of fish, mainly Arctic cod (*Boreogadus saida*) and polar cod (*Arctocadus glacialis*), and crustaceans (amphipods, mysids, and euphausids) (Holst et al. 2001). Ringed seals are relatively sedentary, and males may occupy the same under-ice habitat for up to 9 months (Smith 1987). Ringed seals are hunted in virtually all coastal communities in the Canadian Arctic and it is, therefore, relatively easy to obtain samples with the help of local hunters and trappers committees.

Until this project began, NCP was funding work on temporal trends in seals only at Holman, NWT, in the western Canadian Arctic (Stern and Addison 1999). Addison and Smith (1998) have recently published time trends of PCB, DDE and DDT in ringed seals from 1972-1990 at Holman. There are uncertainties in the pre-1981 Holman trends, because archived samples are not available from 1972 and analytical methodologies have changed (packed columns to capillary gas chromatography [GC] columns). Nevertheless, through reanalysis of 1981 samples by both packed column and capillary column GC, the authors have been able to compare results over the 18-year period.

The rationale for this project is that with only one site for temporal trends, there are significant geographical gaps in temporal trend coverage. Previous work on POPs and metals in ringed seals from the 1980s and 1990s at locations in the high Arctic and in Hudson Bay had not been followed up. There could be differences in the trends of POPs and Hg in the eastern and western Arctic. It is now clear from recent seawater measurements that there are large spatial differences of HCH, toxaphene and PCBs in seawater between the Beaufort Sea and Baffin Bay, and between those areas and Hudson Bay (Hoekstra et al. 2001, Harner et al. 1999, Macdonald et al. 2000, Jantunen and Bidleman 1998). Presumably this reflects the influence of Atlantic water in Baffin Bay and freshwater inputs, which are also relatively low in HCH, in Hudson Bay.

These differences in seawater levels may give rise to differences in contaminant levels in marine food webs and ultimately in marine mammals. For example, in the case of HCH, much higher levels are found in ringed seal blubber from the central high Arctic (Eureka, Resolute, Arctic Bay) than in waters influenced by the Atlantic Ocean (Baffin Bay [Grise Fiord], Cumberland Sound [Pangnirtung] and Ungava Bay). Hudson Bay populations (Arviat, Inukjuaq) have similar levels to those in the central high Arctic, a trend that is not consistent with levels in water. PCB153 shows fewer regional differences after adjusting for the effects of age and sex using analysis of covariance (Muir et al. 2000), but levels of PCBs are generally higher in seals in the eastern Arctic (Muir et al. 1997).

Regional differences in concentrations are even more pronounced for Hg than for POPs in seals with higher levels in the western Arctic (Muir et al. 1997, Wagemann et al. 1996). This may be due to greater sources of natural Hg in the sedimentary rocks of the western Arctic. Temporal trends in Hg show increasing levels with time in seals, beluga, narwhal and seabird eggs (Wagemann et al. 1996, Braune 1999) but the rates do not seem to be the same in the eastern and western Arctic, at least for beluga. In the case of seals, results for Hg in liver are available for several communities in the eastern Arctic (Resolute, Pangnirtung, Inukjuaq, Wakeham) and western Arctic (Holman, Sachs Harbour) from the 1970s to 1990s, although they have been presented only on a regional basis (Wagemann et al. 1996).

Activities in 2000-2001

This is a new project. However, the principal investigators have access to samples, have published on older results and are custodians of the data from the 1970s, 1980s and 1990s. Ringed seal blubber and liver samples collected from Pangnirtung in May 1999 were provided by Dr. Kunito with the research group of S. Tanabe (Ehime University, Japan). Ringed seal blubber samples were obtained from Jones Sound near Grise Fiord as part of the North Water Study (Fisk et al. 2001) and at Arviat as part of studies by I. Stirling and N. Lund (Canadian Wildlife Service) in 1998.

In 2000-2001 ringed seal samples were successfully collected with the help of Hunters and Trappers Committee partner organizations in Resolute, Arctic Bay and Pond Inlet as part of the spring/summer hunt. Hunters were provided with a kit and video prepared in Inuktitut and English by the Nunavik Research Centre (NvRC). Collections consisted of blubber, liver, muscle, kidney and tooth/lower jaw (for aging) from 25 seals; most were adults and about one-half were female. Essential data on length, girth, blubber thickness at the sternum and sex was provided for the Resolute and Arctic Bay animals. All samples were shipped to the NvRC for processing. Large subsamples of all tissues were archived in walk-in freezers at -35°C in sealed plastic bags (double bagged). Aging was performed on tooth sections at NvRC.

Chemical analyses

For 2000-2001, samples from Pangnirtung, Arviat, Grise Fiord and Pond Inlet were analyzed. Ringed seal blubber samples from Grise Fiord and Pangnirtung were analyzed for organochlorines at NWRC, Hull, and samples from Arviat were analyzed at the National Laboratory for Environmental Testing (NLET) at NWRI. A subset from Pangnirtung was analyzed at both laboratories. Procedures were similar to those used for previous NCP work on marine mammals (Fisk et al. 2001, Muir et al. 1999). At NWRC, seal blubber was homogenized with sodium sulfate. This mixture was placed in a glass column and organochlorines were eluted with dichloromethane:hexane (1:1). Organochlorines were isolated by gel permeation chromatography (GPC) followed by chromatography on Florisil. PCBs and organochlorine pesticides were determined by gas chromatography-mass spectrometry (GC-MS) on an HP-5973 MSD using selective ion monitoring. At NWRI, seal blubber was homogenized with sodium sulfate and Soxhlet extracted with dichloromethane:hexane (1:1). Following GPC cleanup, organochlorines were fractionated on a silica gel column, then analyzed by gas chromatography with electron-capture detection (GC-ECD). Separation was accomplished on a HP 6890 GC using a 30 m DB-5 column with H_2 carrier gas. Toxaphene was analyzed at NLET by low resolution GC-negative ion MS using a HP 5973 MSD in negative ion mode.

Liver and kidney samples were analyzed for heavy metals (cadmium, Hg, lead, selenium and arsenic) at NvRC (Kuujjuaq) using atomic absorption spectrometry (AAS).

Quality assurance steps included the analysis of reference materials for heavy metals and organochlorines, reagent blanks and duplicate samples. The NvRC, NWRC and NLET organics laboratories are participants in the NCP Quality Assurance Program and in Quality Assurance for Marine Environmental Monitoring in Europe (QUASIMEME) programs for heavy metals and PCBs, respectively. The NLET and NWRC are certified by the Canadian Environmental Analytical Laboratory program of the Canadian Standards Association.

Organochlorine concentrations in ringed seals were normalized to 100% lipid. Results for both Hg and organochlorines were first tested for normality using skewness and kurtosis tests. Data were $\log_{10}$ transformed to give coefficients of skewness and kurtosis < 2. Mean concentrations of organochlorines in blubber of female ringed seals were compared among years using the general linear models procedure in Systat (Version 9) (SPSS 1999). The analysis of covariance (ANCOVA) model included age, and age* year interaction. Comparisons of least squares means from the ANCOVA were made using Tukey's (Post-hoc) Test. Geometric means (back transformed log data) and arithmetic means were calculated for Hg in liver. For Hg, the ANCOVA model included age, sex, and age* year and sex* year interaction.

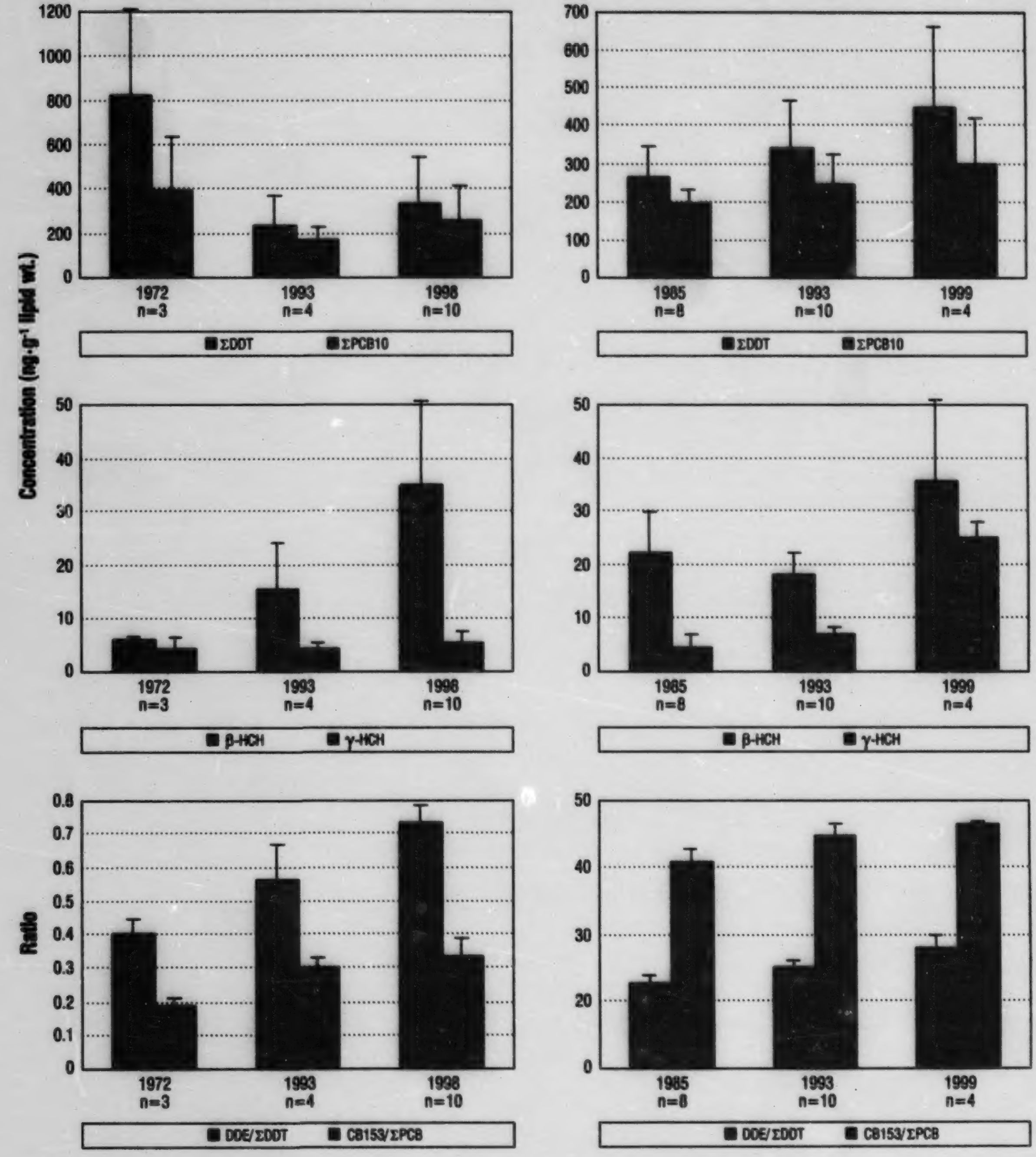
Results and Discussion

Organochlorines

Samples from female seals only were selected for analysis in order to minimize age-related effects on organochlorine levels (Addison and Smith 1974). Results are available for seal blubber samples from Grise Fiord and for a subset of samples from Pangnirtung. Analysis of samples from Arviat is underway, but results were not available in time for this report.

Geometric mean concentrations (± 95% confidence limits, $ng \cdot g^{-1}$ lipid weight) for ΣDDT, PCBs, β- and γ-HCH and DDE/DDT and CB153/ΣPCB ratios in blubber of female ringed seals from Grise Fiord and Pangnirtung are shown in Figure 1. For comparison with earlier data, ΣPCB10 (sum of congeners 28, 31, 52, 101, 105, 118, 138, 153, 156, 180) was used rather than all congeners. Results from early 1990s are from Muir et al. (1997) and Muir (1996), and from the 1980s from Weis and Muir (1997).

Figure 1. Temporal trends of DDT, PCBs, HCH isomers and DDE/DDT and CB153/PCB ratios in blubber of female ringed seals from Grise Fiord and Pangnirtung*



* Results from early 1990s are from Muir et al. 1999 and from 1980s from Weis and Muir 1997. Results fro Grise Fiord for 1972 are from Muir et al. 1988.

Results for Grise Fiord for 1972 are from Muir et al. (1988). All previous results, including the samples from 1972, which were analyzed at NWRC in 1985, were based on capillary GC-ECD with quantitation using authentic standards.

ΣDDT declined significantly (Tukey's test, $p < 0.05$) in samples from Grise Fiord from 1972 to 1993. ΣPCB10 in seals from Grise Fiord in 1972 was marginally higher ($p = 0.06$) than levels in 1993, but was not significantly different from those levels in samples from 1998. At Pangnirtung, no significant differences were found for ΣDDT or ΣPCB10 among samples from 1985, 1993 and 1999, although mean levels were higher in the samples from the 1990s. One explanation for the higher levels in the 1999 animals is that their average age was older (12 years) compared to the 1985 group (2 years). Although concentrations of major organochlorines generally do not vary with age in reproductively active females, there is a gradual increase from young to very old animals (Fisk et al. 2001). Analyses of additional samples from the 1999 Pangnirtung collection will include younger animals so that a more complete comparison will be possible in the near future.

β-HCH increased significantly ($p < 0.05$) in blubber of Grise Fiord animals between 1972 and 1998 (Figure 1) while γ-HCH showed no trend. At Pangnirtung, β-HCH and γ-HCH were both significantly higher in 1999 than in samples from 1985.

DDE/ΣDDT ratios increased significantly between 1972 and 1993 at Grise Fiord and between 1985 and 1999 at Pangnirtung (Figure 1). Ratios of CB153 to ΣPCB10 also increased significantly between 1972 and 1993 at Grise Fiord and between 1985 and 1999 at Pangnirtung.

Mercury

Concentrations of Hg in ringed seal liver from the four locations (sampled 1998-2000) are shown in Table 1. Results for both males and female ringed seals were used for Hg in liver because ANCOVA showed no effect of gender on Hg concentrations. In other words, mean concentrations in males and females were not significantly different. Mercury concentrations ranged widely in adult seals and were highly skewed. However, log transformation reduced skewness and yielded normally distributed data (skewness coefficient < 2). There were also age*location interactions, i.e. different relationships of Hg with age at the four locations, thus no comparisons between locations were attempted at this stage.

Arithmetic mean concentrations of Hg in adult seals from Pond Inlet (2000) were three-fold higher than results reported by Smith and Armstrong (1978) for the same average aged animals. This difference was statistically significant ($p < 0.05$), however, the assumption that the data are normally distributed may not be correct. Results for Arviat and Pangnirtung could not be compared with previous data as there are no published results to our knowledge.

Discussion and Conclusions

The decline in concentrations of ΣDDT and ΣPCB10 in ringed seals from Grise Fiord between 1972 and 1998 was about four-fold for ΣDDT and about two-fold for PCBs. Addison and Smith (1998) found a three-fold decline for ΣDDT at Holman between 1972 and 1991. In the case of PCBs, there are greater uncertainties in the trends from the 1972-1981 data at Holman because archived samples are not available from 1972 and analytical methodologies

Table 1. Concentrations of total mercury in liver of adult ringed seals

					Mercury ($\mu g \cdot g^{-1}$ wet wt) ± 95% CI	
Location	**Year**	**N**		**Age ± SD (years)**	**Arithmetic mean**	**Geometric mean**
Arviat	1998	22	Mean	19 ± 8	23.7 ± 7.0	18.8 ± 8.3
			Range	10 - 36	4.8 - 66.6	—
Grise Fiord	1998		Mean	19 ± 9	28.7 ± 11.2	17.4 ± 21.3
			Range	5 - 32	0.24 - 87.0	—
Pangnirtung	1999	13	Mean	10 ± 6	19.6 ± 16.3	13.4 ± 12.8
			Range	2 - 25	1.2 - 47.4	—
Pond Inlet	2000	15	Mean	4.5 ± 3.0	12.9 ± 9.1	6.7 ± 7.2
			Range	2 - 10	1.1 - 69.8	—
Pond Inlet[1]	1976	33	Mean	5.2	3.8 ± 1.2	—

[1] Source: Smith and Armstrong 1978

have changed (packed columns to capillary GC columns). Nevertheless, through reanalysis of 1981 samples by both packed column and capillary column GC, the authors have been able to compare results over the 18-year period. In the present case the results from 1972 from Grise Fiord consist of samples analyzed by capillary GC with ECD detection on 60 m 5% phenylmethyl silicone bonded columns (0.25 μm film thickness) with automated split-splitless injection system, and are therefore comparable to present day analyses.

Stern and Addison (1999) conducted a temporal trend study on PCBs and other POPs in beluga from Cumberland Sound using archived blubber for four sampling times from the mid-1980s to late 1990s. Their results showed a small but significant decline in PCBs, DDT group and α-HCH, but none for β- and γ-HCH over the 15-year period (Stern and Addison 1999). The seals, collected from the same area, do not show the same trends for PCBs and DDT, nor for HCH isomers. Analyses of additional Pangnirtung samples from 1999 will help address the question. However, the preliminary results illustrate differences due to species feeding behaviour and migratory pattern. Adult ringed seals are more likely full time residents of Cumberland Sound– while beluga are migratory, spending winter on offshore ice of Baffin Bay and the Davis Strait.

In the case of Hg in ringed seal liver, there was a three-fold increase in concentrations at Pond Inlet over the 24-year period from 1976 to 2000. However, this conclusion is based on results from Smith and Armstrong (1978) who appear to have reported arithmetic means. Statistical comparison using ANCOVA with the data from 2000 is problematic because results are probably not normally distributed. Without the raw data from the 1976 Pond Inlet samples, there will be great uncertainty in the conclusion regarding the size of the increase. On the other hand, the two groups of seals were comparable in age, which is an important co-variate for Hg in adult seals. Also, the Hg measurements in seal tissues have been conducted using the same analytical methodology (cold vapour atomic absorption spectroscopy); therefore, analytical differences are not likely to be an issue.

Wagemann et al. (1996) concluded that there was a three-fold increase in Hg in seal liver in the western Arctic (Holman, Sachs Harbour, Paulatuk) from 1972 to 1987-1993 based on a comparison of regression slopes, of Hg versus age. Braune (1999) found a significant, approximately two-fold, increase in Hg in thick-billed murre eggs from Lancaster Sound over the period 1975-1977 to 1998, which is also in accord with the result from Pond Inlet. Further insight into the temporal trends in Hg will come from the analysis of samples from Resolute and Arctic Bay that were collected in 2000. Earlier data (arithmetic means) for Hg in seal liver from those locations are available from Smith and Armstrong (1978) and Wagemann et al. (1996).

Expected Project Completion Date

The project is ongoing; however, the first complete set of temporal trend data representing three or four time points will be completed by March 2003.

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Effects and Trends of POPs on Polar Bears

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Abstract

Temporal trends, 1991-1999, of organochlorines in female polar bears captured at Cape Churchill were determined by analysis of archived biopsy samples taken each year except 1996. Females were chosen because they exhibit little influence of age on residue levels. No significant trends were found for total chlordanes, total DDT, dieldrin and β-HCH. Significant declines, in the order of 20% over the 9 years, were found for total chlorobenzenes, α-HCH and total PCBs. Rates of declines in individual PCB congeners appeared to be faster as the number of chlorines increased (DB99 < CB153 < CB180). However, it is not known how much of this apparent decline was due to other factors, such as condition of the bears. Analysis of trends in chiral signatures of α-HCH, oxychlordane and heptachlor epoxide in these samples is underway in an attempt to determine if the 'age' of these residues has changed over time.

Preliminary analysis of results from immunotoxicology studies carried out in collaboration with the Norwegian School of Veterinary Science in 1999-2000 demonstrated that high PCB exposures of polar bears impair lymphocyte function, IgG concentration and the ability to produce antibodies following immunization of the bears with certain microbes. It is reasonable to assume that PCB exposure is associated with decreased resistance to infections of the polar bears. Furthermore, a negative correlation was found between individual PCBs, oxychlordane and testosterone concentrations and between ΣPCB and testosterone, indicating that PCB and chlordane exposure in polar bears is associated with a decrease in male testosterone concentrations. At the time of writing this report, Norwegian scientists have not completed statistical analysis of the data.

Preliminary data were obtained for in vitro metabolism of four model tetrachlorobiphenyl congeners, β-HCH, α-HCH and *trans*-chlordane. Chlorine substitution pattern had a quantitative effect on rate and extent of in vitro biotransformation of the four PCB congeners. However, the relative rates of in vitro metabolism of the PCBs and other organochlorines did not agree with the relative bioaccumulation potential of these organochlorine compounds in polar bears. The ability of in vitro metabolism studies to mimic those in vivo requires further research.

Key Project Messages

1. PCBs, and possibly chlordanes, affect the immune system of polar bears, which may result in decreased resistance to infections.
2. PCBs and chlordanes are associated with lower testosterone concentrations in male polar bears, with possible effects on reproductive function.
3. Chlorobenzenes, α-HCH and total PCBs declined 15% to 20% in female polar bears in southwest Hudson Bay between 1991 and 1999. There is some indication that PCB trends are slowing and may reach a steady state.
4. Concentrations of chlordanes, DDTs, dieldrin, total HCH and β-HCH did not change significantly during that period.
5. Results of relative rates of metabolism of organochlorines in vitro did not agree with what was expected from relative biomagnification of these compounds. Confounding factors, such as involvement of multiple enzymes and extrahepatic metabolism, need to be factored in. Further research is required.

Objectives

Long-Term

- Determine the effects, at the individual and population level, of persistent toxic organochlorine chemicals and their metabolites in the polar bear.

Short-Term

1. Determine 10-year temporal trends of persistent organic pollutants (POPs) in the Hudson Bay sub-Arctic ecosystem from 1990 to 1999 by analysis of archived polar bear biopsy samples, including changes in enantiomeric composition of α-HCH and chlordane compounds and ratio of α-HCH/β-HCH.
2. Determine if there is selective tissue distribution of the enantiomers of chiral contaminants in polar bears, which may influence target organ toxicity, by analysis of archived polar bear samples.
3. Determine the endocrine disrupting effect of POPs on testosterone and PCB metabolite profiles by in vitro metabolism studies using polar bear liver microsomes.
4. In collaboration with the Canadian Wildlife Service (CWS), Prairie and Northern Region, the Norwegian Polar Institute and the Norwegian Veterinary Institute, determine the immunotoxic effects of PCBs and other organochlorines in polar bears throughout a gradient of exposure (i.e. Hudson Bay, low; Svalbard, high).

Introduction

The study of organochlorine contaminants in polar bears has a long history. One of the first reports of PCBs in wild mammals was in polar bears in the Canadian Arctic (Bowes and Jonkel 1975). In 1982, the CWS began an investigation to identify the whole range of organochlorines that may be accumulating in polar bears. At the time, very little was being done to look at these contaminants in the Arctic environment. The finding of significant concentrations of several chlordane compounds, HCHs and dieldrin in polar bears, as well as the previously known DDTs and PCBs was one of the primary catalysts that resulted in renewed interest by scientists at Environment Canada and the Department of Fisheries and Oceans in research on the presence and significance of organochlorines in the Arctic. This early group formed the nucleus that eventually resulted in the Northern Contaminants Program (NCP), coordinated under the aegis of the Department of Indian Affairs and Northern Development. The identification of organochlorines, their geographical distribution in Canadian polar bears and bioaccumulation in the polar bear food chain were documented in a series of publications in 1988 (Norstrom 1988, Norstrom and Muir 1988, Norstrom et al. 1988, Muir et al. 1988). PCBs and chlordanes, principally the metabolite oxychlordane, were shown to be the organochlorines with the highest concentration in polar bears.

A more ambitious study of the circumpolar distribution of organochlorines in polar bears was undertaken a few years later (Norstrom et al. 1998). The latter study showed that PCBs were lowest in the Bering and Chukchi Seas, fairly uniform in Canada (except for one anomalously high area at the mouth of Viscount Melville Sound), and highest in east Greenland and Svalbard. Chlordanes and chlorobenzenes were fairly evenly distributed throughout the Arctic. HCH concentrations tended to be highest in the Bering and Chukchi Seas, decreasing slightly further east. These results are consistent with anticipated distribution in the atmosphere of organochlorines from principal origins: Asia for HCHs, North America and Europe for PCBs.

In the early 1990s, emphasis shifted to the study of organochlorine metabolites and their potential toxicity in polar bears, because some metabolites were suspected of being involved in reproductive failure of seals in the Baltic Sea in the early 1970s. A number of methylsulfone-PCB metabolites were found to be present in polar bear tissues at 5% to 10% the concentration of PCBs (Letcher et al. 1995). Geographical distribution was found to be similar to that of PCBs. The source of methylsulfone-PCBs was determined to be partly biotransformation of ingested PCBs, but a significant proportion of the methylsulfone-PCBs was bioaccumulated directly from ringed seals (Letcher et al. 1998).

The profile of cytochrome P450 (CYP) enzymes in liver responsible for metabolism of organochlorines in mammals was partially characterized in the male polar bear (Bandiera et al. 1995). The activity of CYP enzymes EROD (ethoxyresorufin O-deethylation) for CYP1A and BROD (7-benzyloxyresorufin O-deethylase) for CYP2B, was determined, along with immunoquantitated CYPIA and CYP2B protein concentrations and chemical residues levels (Letcher et al. 1996). CYPIA is induced by dioxin-like compounds, and CYP2B by a variety of organochlorines as well as drugs and other xenobiotics. CYP1A protein concentrations were found to correlate with dioxin toxic equivalent concentrations (TEQs). Most of the TEQs were due to CB156 and CB157, because the bear was found to easily biotransform the normally recalcitrant CB126 and the mono-*ortho* PCBs, CB105 and CB118, which usually contribute the most to TEQs in high trophic level mammals and birds. Multiple linear regression showed that CYP2B protein concentrations were correlated with a combination of chlordanes and PCBs, but not with either group individually. This provides strong correlative evidence that these two groups are responsible for CYP2B induction. The possibility of immunoquantitating CYP enzymes in liver stored for several years as homogenates at regular freezer temperatures (–20° to –40°) was tested for potential as a biomarker of effects that correlate with CYP1A. It was found that most of the protein was degraded, so this approach could not be used (Bandiera et al. 1996).

Another group of metabolites, the hydroxy-PCBs, were targetted for study because studies with rats and other laboratory animals showed that they bound competitively to thyroid hormone transport proteins (TTR) in blood plasma. Polar bear blood was shown to have very high levels of hydroxy-PCBs, probably because of the bear's superior biotransformation capabilities (Sandau et al. 1998, 2000a). Total hydroxy-PCBs concentration in plasma was twice that of PCBs and ranked as the highest of all the organochlorine classes. The individual organochlorine with the highest concentration in polar bear plasma was 4-hydroxy-CB187 (Norstrom 2000). During the course of this research, a new metabolite of octachlorostyrene, 4-hydroxyheptachlorostyrene, was discovered in polar bear plasma (Sandau et al. 2000b). Its binding capacity to human TTR was determined to be similar to that of T4 itself. The presence of a protein cross-reacting immunochemically with human TTR was confirmed in polar bear plasma, indicating that this new metabolite was likely present in plasma bound to TTR.

The hypothesis was tested that the hydroxy-PCB compounds were affecting thyroid hormone (T4, T3) and vitamin A (retinol) transport in polar bear by analysis of plasma in populations (i.e. southwest Hudson Bay and Svalbard) with a wide range of PCB concentrations. Principal components analysis was used to analyze the data. Four significant components were found that described 65% of the variance (Norstrom 2000). Contribution of individual chemicals to each component was primarily by chemical class. The first principal component (PC1) classified as persistent PCBs, PC2 as hydroxy-PCBs, PC3 as non-persistent PCBs, and PC4 as chlordanes. Total T4 and T3 were not correlated with any component. Retinol was negatively correlated to PC1 (total PCBs), but positively correlated to PC2 (hydroxy-PCBs), in agreement with findings in Norway. This indicated that hydroxy-PCBs were not causing decreased vitamin A co-transport by binding to TTR. The free T4 index was inversely proportional to the residual T4 binding capacity of plasma, and directly proportional to free T4 in fish. Assuming the same is true in polar bears, free T4 would be negatively correlated to hydroxy-PCB concentrations. It is not known what significance this may have for thyroid hormone homeostasis in the bear.

Possible disruption of male sex hormone status in the polar bear was studied by in vitro metabolism of testosterone. Microsomes from 13 male bears prepared in 1993 for the enzyme characterization and activity studies (Bandiera et al. 1995, Letcher et al. 1996) had been archived at liquid nitrogen temperature. After testing for viability, these microsomes were used to characterize the metabolite profile of testosterone in the polar bear and to determine whether the rate of metabolite formation was in any way connected with organochlorine residue levels in liver previously determined (Letcher et al. 1996). The major metabolites were 2β-hydroxytestosterone, androstenedione and 6β-hydroxytestosterone (Norstrom 2000). In rats, testosterone 2β- and 6β-hydroxylation is catalyzed predominantly by CYP3A enzymes and androstenedione formation is catalyzed by CYP2B enzymes. The profile of testosterone metabolites produced by polar bear is different from that produced by male rats, but is similar to that reported for sheep, goats and cattle. A recent study with ringed seals showed that 2β- and 6β-hydroxytestosterone were also the major metabolites of in vitro testosterone hydroxylation in this species (androstenedione formation was not monitored) (Wolkers et al. 1998).

Correlational analysis of testosterone hydroxylase activities with other monooxygenase activities as well as with hepatic organochlorine levels was carried out. There was a reasonably good correlation between all of the testosterone hydroxylase activities and BROD activity (r values of 0.53 to 0.79). There was a weak correlation between rate of testosterone androstenedione formation and concentrations of the highly persistent CB156, CB157, CB170 and CB180 levels (r values of 0.40 to 0.69). A similar correlation was found between testosterone 2β- and 6β-hydroxylase activities with relatively non-persistent CB74, CB85, CB154, CB149 and CB118 (r values of 0.33 to 0.65). The significance of these finding is greater now that Norwegian studies have shown circulating testosterone concentrations in males to be inversely correlated to PCB concentration.

Immunosuppressive effects of organochlorines in polar bears has been shown by Norwegian scientists. Concentrations of IgG in polar bear plasma from Svalbard were strongly negatively correlated to plasma concentrations of PCBs, suggesting a cause-effect relationship (Bernhoft et al. 2000). Immunotoxic effects appear to be the most sensitive endpoint in toxic effects of organochlorines, and warrant thorough investigation.

Activities in 2000-2001

The effects of high PCB exposure on the immune system were studied by comparing the immune functions in male polar bears having high (Svalbard, 1998) and low (Canada, 1999) PCB exposure using a vaccination model with recapture after immunization. Thirty bears at Svalbard and 30 in Canada were immunized with different herpes, reo and influenza viruses and tetanus toxoid to stimulate the production of protective antibodies such as virus neutralizing antibodies, virus hemagglutination inhibition antibodies and toxin neutralizing antibodies. The immunization also included keyhole limpet hemocyanin (KLH) that together with tetanus toxoid would stimulate cell-mediated immune response. Blood was sampled at immunization and 4 to 6 weeks thereafter for detection of antibodies. In addition, in vitro lymphocyte stimulation was performed with mitogens and specific antigens (phytohemagglutinin, concanavalin A, pokeweed mitogen, PPD, lipopolysackarid). By neutralizing virus infections in cell cultures, inhibition of virus hemaglutination and toxin neutralization, the resistance factor was measured directly. Therefore, the effect of PCBs on the infection resistance was measured without being dependent on infection experiments or doing registration in relation to disease outbreaks. The immunological analyses were done by the Norwegian School of Veterinary Science. All immunotoxicological and chemical analysis data were gathered by mid-2000-2001, but statistical analysis has only begun. Some preliminary conclusions are emerging which will be reported herein.

In addition to immune system function, plasma testosterone concentrations were determined in 123 male bears from Canada and Svalbard.

In 2000-2001, five hypotheses, as presented below, were to be tested to address some of the short term objectives.

1. *Temporal trends in contaminant levels in Arctic ecosystems have been identified in the NCP Blueprints as a knowledge gap. From what information is available, the rate of decrease in POPs appears to have slowed. We hypothesize that levels of POPs in the Arctic marine ecosystem are approaching a steady state influenced mainly by global processes, and that this recent trend can be identified for the Hudson Bay marine ecosystem by analysis of biopsy samples from female polar bears.*

Archived biopsy samples from adult (> 5 years) female bears taken in the summer period at Cape Churchill were chosen for each year between 1991 and 1999. Samples were not available for 1996. Sample sizes each year ranged from four to 10 for a total of 53 analyses (average: six per year). Females were used because previous analyses showed that age effects were minimal in females, whereas there was a substantial effect of age on concentration of highly chlorinated PCBs in males. Females come to steady state with their diet faster because of lactational excretion. Females are therefore more likely than males to follow general environmental trends. For comparison with females, biopsies from seven males in 1995 were also chosen. The samples were analyzed for 57 PCB congeners and 28 organochlorines, including tetra-, penta- and hexachlorobenzenes, three HCH isomers, 12 chlordane compounds, dieldrin, mirex, photomirex, octachlorostyrene, DDE, DDD and DDT. Significance of temporal trends was determined by linear regression using Statistica.

2. *Biochemical reactions involving chiral chemicals are highly enantiomer-selective, therefore knowledge of the concentration of the enantiomeric forms of chiral contaminants is important in determining toxic effects of exposure to those contaminants.*

Determination of enantiomer fractions (Harner et al. 2000) of α-HCH, heptachlor epoxide and oxychlordane is proceeding on pooled samples from each year from the temporal trend study above. These are the only chiral organochlorines in sufficiently high concentration to measure enantiomers. Changes in enantiomer fractions (EFs) over time will indicate if the 'age' of the residue is changing. This is especially important for oxychlordane, which is a persistent compound formed by metabolism of chlordane and nonachlor compounds in birds and mammals. Oxychlordane is recycled into the food chain by excretion from, or death of, the animal. A sub-group of males are being analyzed to determine if there are differences in EFs between genders.

Fat, blood, brain, testis, liver and muscle tissue samples from four male polar bears from the Barrow Strait area in 1993 (Letcher et al. 1996) are being analyzed to determine if there are differences in tissue distribution of enantiomers of chiral POPs.

Due to difficulties with instrument sensitivity, the analysis could not be started until a new GC-MSD had been purchased. Consequently, the chiral determinations were begun late in the fiscal year, are still ongoing, and could not be completed in time for this report.

3. *The rate of metabolism of* PCBs *is dependent upon the number and position of chlorines on the* PCB.

Individual PCB congeners were incubated with individual or pooled liver microsomes from polar bears for 15 to 60 minutes at 37°C. After extraction and clean up, the amount of PCB remaining was determined by gas chromatography. Initial experiments were conducted with pooled rat liver microsomes to optimize assay conditions. Conditions were optimized for metabolism of symmetrically substituted tetrachloro PCBs: CB47 (2,4-2´,4´), CB52 (2,5-2´,5´), CB66 (2,4-3´,4´), and CB77 (3,4-3´,4´). These represent some of the most common substitution patterns in PCBs. V_{max} (rate of metabolism at enzyme saturation) was determined for these four congeners.

4. *The biotransformation capacity (metabolic index), as determined by* PCB *and* OC *metabolism in an in vitro assay, determines the pattern of bioaccumulation and toxicity risk for these compounds.*

The hepatic microsomal CYP-metabolism of *trans*-chlordane, α-HCH and β-HCH was evaluated using a metabolism assay similar to the one developed to measure PCB metabolism. Individual HCH congeners were incubated with individual or pooled liver microsomes from polar bears. After extraction and clean up, the amount of HCH remaining was determined by gas chromatography.

5. PCB *congeners with different patterns of chlorine substitution are biotransformed by distinct cytochrome* P450 *enzymes.*

We have not carried out any experiments to address this hypothesis because of insufficient time. Setting up the assays (Hypotheses 3 and 4 above) proved more difficult than anticipated.

Results

Temporal trends of organochlorines in Hudson Bay polar bears

Temporal trends of the major organochlorine groups found in polar bears are presented in Figure 1. Probability that a significant trend exists in female bears is also given. There were statistically significant ($p < 0.05$) downward trends of total chlorobenzenes (ΣCBz), α-HCH and PCBs. There were no significant ($p < 0.05$) changes in chlordanes, DDTs (mostly 4,4'-DDE), dieldrin, β-HCH and Σ-HCH.

There were no statistically significant ($p < 0.05$) increasing trends in female bears over the whole 9 years. However, since 1995 ΣDDT had a tendency to increase. This is likely part of an unexplained oscillation. ΣDDT concentrations in polar bears seem to be subject to more variation than other organochlorines. Historical concentrations of ΣDDT in northern Hudson Bay were 884 $ng{\cdot}g^{-1}$ (1968), 525 $ng{\cdot}g^{-1}$ (1984) and 148 $ng{\cdot}g^{-1}$ (1989) (Muir and Norstrom 2000). Thus, present concentrations of ΣDDT in Hudson Bay bears are approximately 25% of those during the period of active DDT use.

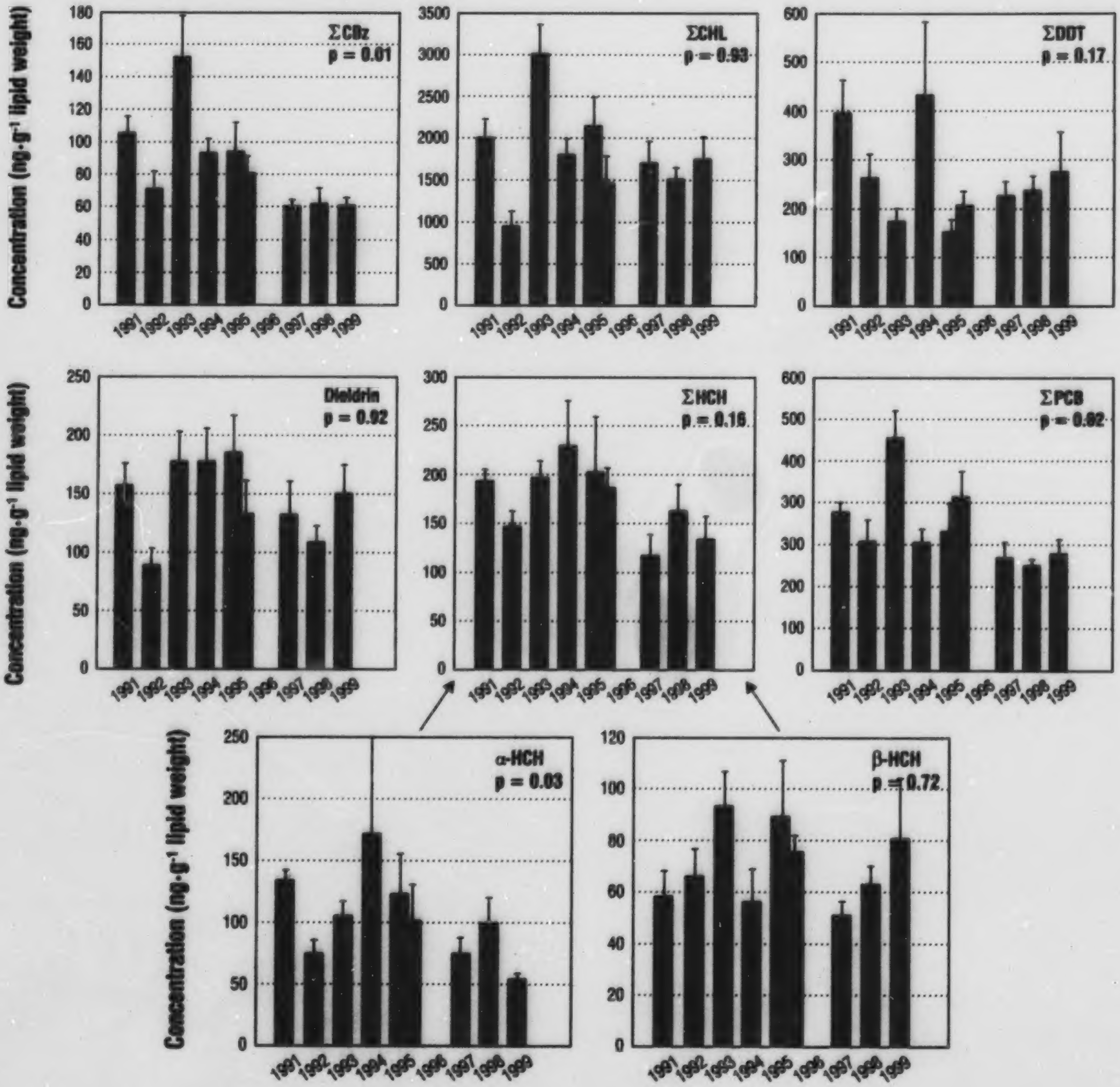
The changing composition of ΣCBz over time is shown in Figure 2. HCBz and 1,2,4,5-TeCBz were each roughly half of the total, with a minor contribution from PnCBz. The proportion of 1,2,4,5-TeCBz peaked at 53% between 1995 and 1997, then decreased to values similar to the pre-1995 period, 40% to 45%. Most of the decline in ΣCBz was due to HCBz, which had a half-life of approximately 9 years.

ΣPCB decreased fairly steadily throughout the 1990s, with a half-life of approximately 18 years. The shift in composition of the PCBs was subtle over the decade, but there was a clear tendency for the proportion of less chlorinated congeners to increase, and the highly chlorinated congeners to decrease. Thus, CB99 increased from approximately 10% to 12% of ΣPCB, CB153 was relatively stable at approximately 35% and CB180 decreased from 17% to 14%. The trends in these three congeners indicates that the half-life of CB153 (19 years) was similar to that of ΣPCB. The half-life of CB180 (13 years) was shorter and that of CB99 (> 50 years, not significant) was longer than ΣPCB. Thus, the decreasing trend in ΣPCB is driven by loss of the highly chlorinated congeners. Historical concentrations of PCBs in polar bears from northern Hudson Bay were as follows: 3820 $ng{\cdot}g^{-1}$ (1968), 7130 $ng{\cdot}g^{-1}$ (1984) and 4600 $ng{\cdot}g^{-1}$ (1989) (Norstrom and Muir 2000). Thus, PCB levels in the early 1990s in Hudson Bay were similar to those in the late 1960s, in sharp contrast to the situation in areas such as the Great Lakes or the North Atlantic, where PCBs were in the order of 10 times higher in the late 1960s and early 1970s than at present. Peak PCB concentrations in Hudson Bay may have occurred earlier than 1984, but there are no data for the 1970s. The rate of decline of PCBs appears to have been faster in the 1980s (half-life of 7 to 9 years) that in the 1990s. This may indicate that Hudson Bay is approaching equilibrium with global distribution of PCBs, and further decreases may be slight.

The trend of ΣHCH was not significant because of the contribution from β-HCH, the concentration of which remained very stable throughout the 1990s. Traces of γ-HCH were occasionally found, but could not be reliably quantitated. Less than 2% of SHCH was γ-HCH in the great majority of samples. The apparent half-life of α-HCH in the 1990s was approximately 10 years, very similar to that of HCBz. Historical concentrations of ΣHCH in northern Hudson Bay showed trends similar to those of PCBs, that is, maximum concentrations occurred in 1984, but the peak was much shallower: 235 ng·g^{-1} (1968), 335 ng·g^{-1} (1984), 252 ng·g^{-1} (1989). Present ΣHCH concentrations are approximately 50% of peak, but a significantly higher percentage is β-HCH.

Concentrations of organochlorines in males in 1995 were similar to those in females. There was a tendency for most

Figure 1. Temporal trends of major organochlorine residue classes in adipose tissue biopsy samples from female polar bears, southwest Hudson Bay, 1991-1999; mean ± SE, n=4-10*



* Blue bars are males, 1995, n=7. Level of significance of temporal trends given for each class.

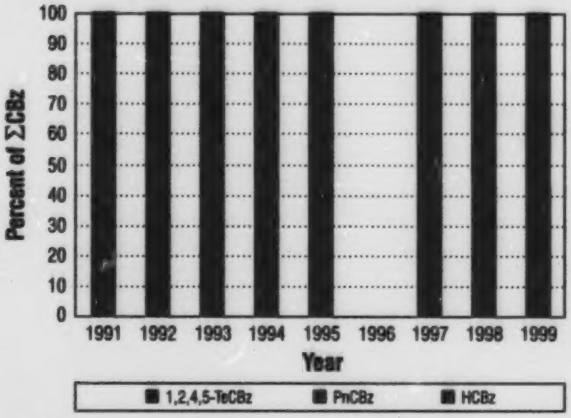
residues to be lower in males, except PCBs and DDTs, which were slightly higher in males. These tendencies were not significant for the most part. The difference in PCBs between males and females was not as large as observed in more extensive data sets. Norstrom et al. (1998) showed that males had 40% higher PCBs than females on average. However, there was significant effect of age on male PCB levels. Younger male bears have PCB concentrations closer to those in females, which may explain the similarity between males and females in 1995. Lower levels of PCBs and lack of an age effect in females are presumed to be due to the additional losses from lactation. Males had 30% lower levels of chlordanes than females, which is the same as that found by Norstrom et al (1998). Polischuk et al. (2001) showed that males are capable of metabolizing chlordanes during a seasonal fast, while females are not. The enhanced metabolic capability of males therefore explains the lower levels of chlordanes, and possibly some of the other compound groups, in males.

Immunotoxicology

Methodology for assessment of white blood cell activities under field conditions was developed by the Norwegian School of Veterinary Science. This is important for studies of cell biology, physiology and immunology in polar bears. It further represents the basic methodology for measuring cell-mediated immunity to microbes needed for testing how environmental pollutants, infections, nutritional factors, starvation and stress influence lymphocyte function.

Significantly lower lymphocyte responses to lipopolysaccharide from E. *coli* and *Mycobacteria* were found in polar bears with high PCB156 concentration in the blood. In vitro exposure to selected PCB congeners of mitogen induced lymphocyte cultures was found to suppress the lymphocyte response, with the strongest reduction in cultures from polar bears having the highest plasma concentration of PCBs. The present study confirmed our previous finding of a significant inverse correlation between IgG and PCBs, both ΣPCB and specific congeners (PCB 99, 118 and 194).

Figure 2. Composition of ΣCBz in female polar bear adipose tissue, southwest Hudson Bay, 1991-1999

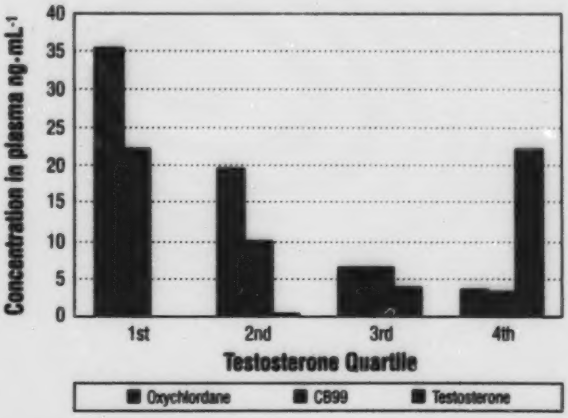


The vaccination study revealed significantly higher plasma concentrations of PCBs 118, 156, 180 and 194 in polar bears from Svalbard as compared to Canada, but significantly higher antibody titres to influenza, reo and herpes viruses in Canada as compared to Svalbard. These results, together with the fact that there was inverse correlation between IgG and PCB 99, 118 and 194 in the same material, demonstrate that the effect of PCBs on the IgG concentration is associated with decreased ability to produce antibodies following immunization.

Impaired antibody production following immunization and decreased specific lymphocyte response in polar bears with high PCB exposure indicated decreased resistance to infections. This is supported by the findings that polar bears with high plasma PCB have been more exposed to the *Pasteurella* bacteria, one of the most common microbes in the environment, which attacks the respiratory system.

Preliminary statistical analysis of testosterone concentrations in male bears revealed that they were negatively correlated with concentrations of individual PCBs and ΣPCB in plasma (Derocher et al. 2000). Figure 3 presents a contrast between mean plasma testosterone concentrations in each quartile and concentrations of two

Figure 3. Distribution of mean testosterone, oxyxhlordane and CB99 concentrations by testoterone quartile, in 123 male polar bear plasma samples from Southwest Hudson Bay and Svalbard



* Source: Derocher et al. 2000.

of the major organochlorine residues which negatively correlated the most strongly with testosterone. Testosterone concentrations were also strongly positively correlated with age. Final conclusions concerning the correlation between organochlorines and testosterone must factor in the effect of age. Because PCB concentrations tend to increase with age of male bears, it is not obvious why testosterone concentrations would be negatively correlated to PCBs.

In vitro metabolism of organochlorines

The PCB metabolism assay proved difficult to set up due, in part, to the time- and labour-intensive extraction procedure which limited the throughput of the assay. Another problem was that the method of analysis used to determine the rate of metabolism was not very sensitive or reproducible. We used a subtraction method that measures disappearance of the substrate rather than a more sensitive method that measures formation of product(s). The assay was optimized for metabolism of the four tetrachloro PCB congeners at enzyme saturation to enhance the ability to compare rate of metabolism among compounds and activity for a compound among individual animals. Results are presented in Table 1.

For this bioassay to be meaningful, the relative V_{max} values should be proportional to rate of metabolism of the these compounds in vivo. This can be tested indirectly by considering relative biomagnification factors, which should be inversely proportional to V_{max}. This appears to not be the case. Of all the tetrachloro congeners, CB47 has the highest biomagnification potential (Letcher et al. 1998, Muir et al. 1988, Norstrom et al. 1988). The greater resistance of the 2,4 substitution to biotransformation relative to 3,4 is demonstrated in vivo by the much higher relative biomagnification factor of CB99 (2,3 to 2,4,5) to CB105 (3,4 to 2,4,5) (Letcher et al. 1998). Of all the congeners, CB52 is expected to be metabolized the fastest using the biomagnification criterion (Letcher et al. 1998). Letcher et al. (1996) showed that the relative biomagnification potential of 3,4-substituted PCBs was much less than that of 2,4-substituted PCBs. Taken together, the expected order of decreasing ease of metabolism from a knowledge of biomagnification factors is therefore CB52 ≥ CB77 > CB66 > CB47, whereas the data in Table 1 suggest CB47 = CB52 > CB66 = CB77.

The reason for the inability of the bioassay to duplicate the order of in vivo biotransformation rates of PCB congeners is unknown. The amount of PCB that had to be added to achieve enzyme saturation was relatively high, although below the solubility limit. It is possible that the apparent V_{max} is lower than the true value due to deactivation of the enzyme by binding of the substrate to the enzyme without metabolism. It is probable that more than one enzyme is involved in the metabolism of these congeners (CYP1A for CB77 and CB66, CYP2B for CB52), and perhaps the relative activities of these enzymes in vitro is different from that in vivo. Another possibility is that enzymes in other tissues, such as the gut endothelium, may be involved in metabolism of some compounds via a constitutive enzyme which is not present in liver microsome preparations. Thus, the microsomal metabolism assay would not be representative of metabolic capability of the intact animal.

The assay conditions were also optimized for metabolism of α-HCH and β-HCH by polar bear microsomes. Rates of metabolism of *trans*-chlordane, α-HCH and β-HCH at various concentrations in the medium are given in Table 2. Saturation (rate independent of substrate concentration) was achieved for *trans*-chlordane, approached for α-HCH and not achieved for β-HCH, with initial HCH concentrations up to 22.6 mM. This concentration is approaching the solubility limit of these compounds in the medium. Nevertheless, the ranking of ease of metabolism in this assay is clearly β-HCH > α-HCH > *trans*-chlordane. As was the case for the tetrachloro PCB congeners, these results are counter-intuitive to our understanding of relative rates of metabolism based on relative biomagnification factors. The ratio of β-HCH to α-HCH in polar bears during the mid-1990s (Figure1) was higher (~ 0.56) than in ringed seal from Hudson Strait (0.26, Braune 2001). This suggests that metabolism of α-HCH > β-HCH in the bear, not the inverse. The biomagnification factors of α-HCH and *trans*-chlordane from seal to bear were found

Table 1. Relative rates of in vitro metabolism of four tetrachloro PCB congeners by pooled male polar bear microsomes

PCB congener	Saturating substrate concentration (μM)	Approximate Vmax value (pmol PCB metabolized·min^{-1}·mg protein^{-1})	Substrate concentration (μM) at 0.5 V_{max} (Michaelis constant)
CB47 (2,4-2′,4′)	100	1200-1300	50
CB52 (2,5-2′,5′)	100	1000-1200	50
CB66 (2,4-3′,4′)	40	300-350	10
CB77 (3,4-3′,4′)	20	240-260	4

Table 2. Effect of substrate concentration on activity of polar bear microsomes in the in vitro metabolism of α-HCH, β-HCH and *trans*-chlordane

Initial concentration of α-HCH (mM)	Activity (pmol·min^{-1}·mg protein^{-1})	Initial concentration of β-HCH (mM)	Activity (pmol·min^{-1}·mg protein^{-1})	Initial concentration of *t*-chlordane (mM)	Activity (pmol·min^{-1}·mg protein^{-1})
22.6	3711	22.6	7618	14.28	1027
15	2964	15	4181	10	1041
10	1701	10	2495	5	959
5	528	5	1911	1	152
2.5	363	2.5	479	0.25	34
1	230	1	510	0.1	26
0.5	129	0.5	217	0.05	14
0.1	43	0.1	43	0.01	6
0.05	18	0.05	21		
0.01	4	0.01	5		

to be 0.016 and 0.0004, respectively (Wiberg et al. 2000). Values significantly < 1 indicate that both compounds are biotransformed readily in the bear, but that the rate is ~ 40 times faster for *trans*-chlordane than α-HCH. The disagreement between this fact and the bioassay results is difficult to reconcile unless a significant proportion of the metabolism of *trans*-chlordane in vivo is extra-hepatic, and therefore not accounted in the bioassay.

Unmistakably, in vitro microsomal metabolism assays of common organochlorine contaminants by polar bear microsomes as currently designed do not represent what is occurring in vivo, based on biomagnification potential of these compounds from seal to bear. The reasons for this may be several, including extra-hepatic metabolism in vivo, involvement of multiple enzymes in the metabolism with different relative activities in vitro than in vivo and different substrate specificities, and inability to optimize conditions (e.g. lack of a cytosolic factor, solubility of the substrate).

Discussion and Conclusions

The focus of this project in early years was chemical identification and spatial/temporal trend analysis. This gradually evolved into emphasis on identification and tissue distribution of persistent metabolites of these compounds, principally of PCBs. The effects of metabolites on circulating levels of thyroid hormones and vitamin A were studied. The liver enzyme systems involved in metabolizing organohalogen compounds and their activities were characterized. Induction of xenobiotic metabolizing enzymes was shown to be correlated with exposure to organochlorine contaminants. In collaboration with Norwegian scientists, the immune system of the bear has been examined, and influence of halogenated organic chemicals on immune function researched. Norwegian scientists have also studied possible effects of organohalogen compounds on circulating male and female hormones. Whole body toxicokinetics of organohalogen compounds (in some cases, by recapturing individual bears) have been documented. The influence of seasonal fasting, transfer to cubs by lactation, gender differences in metabolic capability, effects of age on concentrations are a few other factors that have been documented as well.

Thus, we presently have very good knowledge of the identity, concentrations and spatial distribution of halogenated organic contaminants and their persistent metabolites in various tissues of polar bears (arguably better than any wildlife species), quite solid information on the function of some of the vital systems which may be affected by these chemicals, indications of where some effects may lie, knowledge of whole body toxicokinetics, and good information on feeding ecology and population biology. Much of this wealth of information has not yet been published. Drawing on all sources of information, the following points summarize current state of knowledge of exposure and ecotoxicology of the major halogenated organic compounds in polar bears.

- Organochlorine compounds, principally six PCB congeners (CB99, CB153, CB138, CB180, CB170 and CB194) and oxychlordane are the major halogenated organic contaminants in polar bear tissues, except blood (hydroxy-PCBs) and brain (a-HCH), because of high biotransformation capability of the bears.

- TCDD, CB118, CB105, CB77 and CB126 are all readily metabolized by polar bears. Most of the TCDD TEQs in the bear are contributed by the mono-*ortho* heptachloro PCBs, CB156 and CB157.
- More volatile organochlorines, such as chlorobenzenes, HCHs, chlordanes and dieldrin are fairly evenly distributed in polar bears around the Arctic; however, only the chlordanes are biomagnified to any extent and are of toxicological importance.
- PCBs are the least evenly distributed of organochlorines. Lowest levels are found in the Bering and Chukchi Seas. Levels increase westward across Canada, but differences are not large among areas, except at the mouth of Viscount Melville Sound, where PCB levels are inexplicably two or more times higher than other areas in North America. PCB concentrations are similarly higher in east Greenland and Svalbard, probably due to substantial input from Europe. Analysis of blood samples by Norwegian scientists indicates that even higher levels may be found in bears from western Russia. Polar bears from this area of Russia may have PCB concentrations of approximately 100 $\mu g \cdot kg^{-1}$ (ppm) in fat.
- Polar bears metabolize DDT and DDE rapidly; therefore, concentrations are low. However, they may be subjected to greater risk of adrenotoxic effects of methysulfone-DDE metabolites, which have been identified in liver and fat.
- Methylsulfone-PCB metabolites are present in most polar bear tissues at approximately 5% to 10% of PCB concentrations. A significant proportion of these compounds are probably bioaccumulated from seals.
- Hydroxy-PCB metabolites of PCBs are the group of organochlorine compounds in polar bear plasma with the highest concentrations, presumably because of strong binding to the thyroxine (T4) transporting protein, transthyretin (TTR), but possibly other proteins.
- A protein immunochemically cross-reactive with human TTR has been identified in polar bear plasma.
- Correlative evidence strongly suggests that hydroxy-PCBs, and not PCBs or other organochlorines, are responsible for disruption of some parts of the thyroid hormone transport system, presumably by competitive binding to TTR. There appears to be some inconsistency in findings of Norwegian and Canadian groups. The nature of this disruption, and whether it is of significance to thyroid hormone homeostasis, therefore requires further exploration.
- Plasma Vitamin A concentrations are negatively correlated to PCB concentrations, but not to hydroxy-PCBs. Disruption of Vitamin A homeostasis by PCB exposure may therefore be due to mechanisms other than interference with retinol transport in plasma by hydroxy-PCB binding to TTR. PCBs are known to affect retinol storage in liver. Further investigation is required to determine the mechanism and significance.
- Norwegian results suggest that circulating levels of testosterone in males are reduced by PCB or other organochlorine exposure, possibly affecting reproductive function.
- Rate of production of some testosterone metabolites in vitro by male polar bear liver fractions is positively correlated with PCB and other organochlorine concentrations in the livers, indicating that CYP enzyme induction may be a primary toxic effect, rather simply an indication of exposure, by an increasing rate of androgen metabolism.
- Correlative evidence shows that PCBs and oxychlordane are most likely responsible for induction of CYP2B, possibly other liver enzymes, which may metabolize testosterone in the polar bear.
- In vitro metabolism studies of PCBs and organochlorines yields results inconsistent with known biomagnification of these compounds. The usefulness of in vitro metabolism studies to predict in vivo behaviour is questionable until further research is done.
- Females that lost their cubs, between emerging from the den and the following summer/fall in southwest Hudson Bay, had significantly higher organochlorine concentrations than females that kept their cubs. Although the difference in concentrations may be due to lack of lactational transfer as a result of loss of cubs, the possibility exists that high exposure to organochlorines in milk affects cub survival.
- The hypothesis that pseudo-hermaphroditism found in some female polar bear cubs at Svalbard has an organochlorine exposure/endocrine disruption etiology is not strong because of occurrence of the same syndrome in black bears.
- Exposure to PCBs and other organochlorines suppresses circulating concentrations of IgG, antibodies to influenza, reo and herpes viruses, and lymphocyte responses. Incidence of *Pasteurella* bacteria exposure is higher in high PCB bears. Impaired resistance to infection is indicated in bears with high organochlorine exposure. These results confirm that immune system

impairment is one of the most sensitive measures of organochlorine toxic effects.

This project was completed in 2000-2001. There is still a lot of work to do, especially in polar bear ecotoxicology. As outlined in the Introduction, polar bear investigations have been in the forefront of identifying, scoping and tracking problems associated with persistent organic contaminants in Arctic ecosystems. The circumpolar distribution of the species, simplicity of the food chain, high trophic level, penchant for eating seal fat, relative ease of non-destructive (but costly) sampling of tissues (subcutaneous fat, plasma, hair), good knowledge of its biology, most-at-risk species categorization and emerging evidence of toxic effects, call for continuing this research. If not through the NCP, other means should be sought. The major stumbling block in polar bear ecotoxicology in Canada at present is as much a lack of leadership as a lack of funding. However, this project has been an excellent training ground for environmental toxicologists and chemists over the years (two Ph.D.s at Carleton University and one at University of Saskatchewan), and it is to be hoped that the next generation of scientists will take up the challenge.

Project Completion Date

Completed March 31, 2001

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Yukon Traditional Foods Monitoring Program

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Yukon Contaminants Committee

Abstract

The Yukon Contaminants Committee (YCC) has long supported the monitoring of contaminants within the foods most commonly collected in the Yukon. It was originally intended to review First Nations traditional/ country foods, however, after research in 1991 resulted in a fish consumption advisory, the monitoring has become more focussed. Over the past 10 years, the majority of traditional foods consumed in the Yukon have been tested for contaminants and have been found to be safe for consumption. The current focus of temporal trend monitoring for organochlorines and heavy metals in lake trout, burbot, salmon and caribou, from specific locations. Quiet Lake and Kusawa Lake have been selected for trend monitoring of lake trout and burbot. Salmon are collected from three geographically diverse locations in the Yukon, with the assistance of the Department of Fisheries and Oceans. Caribou are sampled through a hunter collection program and with the assistance of the Yukon government. Lake trout and burbot will be collected from Quiet and Kusawa Lakes in 2000-2001 and held for analysis. Salmon will be collected from the Klukshu River, Fishing Branch River and Yukon River at Whitehorse, and sent to the Department of Fisheries and Oceans in Winnipeg for analysis. Results of all past and future sample analysis are/will be held within then Yukon Contaminants Database. This is supplemented by an active archive of samples maintained for future use for emerging contaminants issues identified through Northern Contaminants Program research.

Key Project Messages

1. Regular sampling of Yukon traditional/country foods has taken place since 1991.
2. All analytical results are contained in the Yukon Contaminants Database.
3. Archived samples are maintained for future use.
4. Most of the traditionally harvested foods in the Yukon are safe to eat.
5. Temporal trend monitoring insures that the Yukon will be aware of any changes in contaminants levels in its traditional/country foods.

Objectives

1. Monitor the most commonly harvested fish and mammal species for changes in contaminants levels.

2. Collect the results within an available database for the use of the Yukon public and researchers.
3. Collect and preserve a sample archive for use in dealing with future emerging issues.
4. Communicate the annual sample results.

Introduction

Sampling of fish in Lake Laberge in 1991 resulted in the issuing of a food consumption advisory on lake trout flesh and burbot livers, which is still in place. The Yukon Contaminants Committee (YCC) then began a systematic evaluation of all traditional/country foods consumed by First Nations and the general public. The investigation was conducted over several years and evaluated by Health Canada and the Centre for Indigenous Peoples' Nutrition and Environment (CINE).

Over the years, in consultation with these organizations, the YCC has focussed the investigation to several fish species and caribou, collected from consistent locations in the Yukon. Lake trout and burbot are collected from Quiet Lake and Kusawa Lake. The initial investigation had indicated that these two species were the most likely to carry elevated levels of persistent organic pollutants (POPs). The two lakes were selected as having no direct input of POPs, containing both species of fish, having small watersheds, and being accessible. Salmon were originally collected from traditional aboriginal fishing locations, but this has since been changed to existing fish weir locations in the same areas, for ease of sample collection. The salmon species collected are chinook, chum and sockeye.

Salmon were collected in the original regions, but for the first time with the assistance of the Department of Fisheries and Oceans (DFO) weir facilities. DFO operates a number of salmon monitoring weirs across the Yukon and their staff generously offered to collect salmon from weirs in the same areas that had been sampled in the past. This coordinated effort of collection has a number of advantages for the program: it is tremendously cost effective to receive salmon from DFO staff who are commuting in and out of these areas already; the salmon collected are from mortalities at the weir, so no salmon are being sacrificed to research; and it allows the sampling to continue without removing this valuable and diminishing resource from traditional food fisheries.

Caribou are collected through a unique hunter submission program operated through the Yukon Government's Department of Renewable Resources. Samples of tissue from these submissions are monitored for heavy metals only, as past research indicated that there were little or no POPs within these mammals' tissues.

All of the past results and those of any future sampling are stored within the Yukon Contaminants Database. This database is available through the YCC.

Activities in 2000-2001

Samples of trout and burbot were collected from Quiet and Kusawa Lakes to be archived for future analysis. Salmon were collected at DFO weirs on the Klukshu River, Fishing Branch River, and at the Whitehorse fish ladder on the Yukon River, and sent for analysis.

Results

The results for the salmon indicate that the levels of POPs within their tissue remain extremely low and that the fishery continues to be safe for consumption.

Discussion and Conclusions

Past and present sampling indicates that the majority of traditional/country foods continue to be a safe and healthy component in the diet of Yukon people. The example of Lake Laberge reminds us that this may not always be the case and that annual monitoring of selected indicator species is essential to maintain confidence in Yukon traditional/country foods. The Northern Contaminants Program continues to identify emerging contaminants and, as this knowledge progresses, an archive of samples is being collected to help answer questions that may arise from this new information.

The monitoring program continues to be a cost-effective way of maintaining confidence in the consumption of traditional/country foods enjoyed by all Yukon peoples. The efficiency of this program continues to grow through the adjustment of collection strategies and the emphasis on linkages with government agencies involved in the management of the wildlife resource. Through the direction of the YCC, what had begun as a scientific survey, has evolved to be a showcase monitoring program for contaminants in the North. The program will be able to adapt to emerging issues through the maintenance of a sample archive which allows us to step back in time, and the Yukon Contaminants Database provides a unique communications ability.

Expected Project Completion Date

This project is ongoing.

Acknowledgments

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Temporal Trends of Organochlorine, Organobromine and Heavy Metal Contaminants in Burbot from Fort Good Hope, Northwest Territories

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Abstract

Muscle and liver samples from burbot collected at Fort Good Hope (Rampart Rapids), Northwest Territories in 2000 were analyzed for mercury, selenium and arsenic. These data, combined with existing data from 1985, 1989, 1993, 1995 and 1999 cover a time span of 15 years. No significant correlation between length and mercury concentration was observed in muscle or liver for either sex. In males, mean mercury concentrations in muscle increased by 36% over the 15-year time period from 1985 to 2000. Mean mercury concentrations in muscle and liver over the entire data sets were 0.295 ± 0.112 ($n = 108$) and 0.064 ± 0.049 ($n = 102$) $\mu g \cdot g^{-1}$, respectively. Muscle mercury levels are below the recommended guideline level of 0.50 $\mu g \cdot g^{-1}$ for commercial sale but are at, or exceed, the guideline level of 0.2 $\mu g \cdot g^{-1}$ recommended for fish used for subsistence.

Key Project Messages

1. Mean mercury (Hg) concentrations in muscle from male burbot from Fort Good Hope have increased by 36% over the 15-year time period from 1985 to 2000.
2. Muscle Hg levels are below the recommended guideline level of 0.50 $\mu g \cdot g^{-1}$ for commercial sale but are at, or exceed, the guideline level of 0.2 $\mu g \cdot g^{-1}$ recommended for fish used for subsistence.
3. Total polybrominated diphenyl ether (PBDE) concentrations in liver samples ranged from 628 to 2895 $pg \cdot g^{-1}$.

Objectives

To document the temporal trends of bioaccumulating substances such as heavy metals (Hg, selenium [Se], arsenic [As], organochlorine contaminants (OCs) (e.g. polychlorinated biphenyls [PCBs], DDT, toxaphene, coplanar PCBs) and selected current use chemicals such as short chain polychlorinated-*n*-alkanes (PCAs) and polybrominated diphenyl ethers (BDPEs) in burbot liver (and muscle for metals) from Fort Good Hope, Northwest Territories, so as to determine whether contaminant levels in the fish and thus exposure to people living in Arctic communities who consume them as part of their traditional diet, are increasing or decreasing with time. These results will also help to test the effectiveness of international controls.

Introduction

With a few exceptions, minimal or no direct temporal trend information on OCs and heavy metals in fish are available in either the Arctic marine or freshwater environments. Much of the temporal trend data that is available are too limited to be scientifically credible because they are based on two or at most three sampling times. In addition, much of this is confounded by changes in analytical methodology as well as variability due to age/size, or dietary and population shifts (Muir et al. 1996, Arctic Monitoring and Assessment Programme 1998). By comparison, temporal trend data for contaminants in Lake Ontario lake trout (Borgmann and Whittle 1991) and in pike muscle from Storvindeln, Sweden (Arctic Monitoring and Assessment Programme 1998) are available over a 15- to 30-year period.

Very few measurements have been made of the toxic coplanar (or non-*ortho* substituted) PCBs and other planar OCs in Arctic fish, however, where coplanar PCBs have been measured along with PCDD/PCDFs, PCNs and CDPEs, calculations of TCDD equivalents (TEQs) show that the coplanar PCBs, especially CB126, account for most of the TEQs (Muir et al. 1996). As a result, one of the priorities outlined in both the *Canadian Arctic Contaminants Assessment Report* (Jensen 1997) and the *Arctic Monitoring and Assessment Report* (Arctic Monitoring and Assessment Programme 1998) is for additional measurements of coplanar PCBs in Arctic fish. Measurements of PCDD/PCDF were not recommended unless specific sources are suspected. Because of their toxicological significance, analysis of new chemical contaminants (i.e. those not currently identified in the United Nations Economic Commission for Europe Long-range Transboundary Air Pollution protocols) such as PCAs and BDPEs are essential and will provide a "baseline" against which future measurements can be compared.

Burbot is a predatory, bottom-feeding species of fish. Its sedentary nature and high lipid content of the liver make the species very suitable for monitoring lipophilic contaminants (Muir et al. 1996, Arctic Monitoring and Assessment Programme 1998). As outlined in the Northern Contaminants Program Phase II Call for Proposals (Blueprint for Monitoring the Health of Arctic Peoples and Ecosystems and the Effectiveness of International Controls (Northern Contaminants Program 2000), some of the most comprehensive temporal trend data that exists is for OCs in burbot liver from Fort Good Hope (1986, 1989 and 1994). Annual data also exists for Hg and Se in both burbot muscle and liver for the years between 1985 and 1999 (Wagemann 1985, Lockhart et al. 1989, Lockhart 1999, Stern et al. 2000a).

Activities in 2000-2001

In December 2000, 36 burbot were collected from the Mackenzie River at Fort Good Hope (Rampart Rapids) by community residents. The heavy metal analyses have been completed and OC analyses are underway. The burbot were not shipped to the Freshwater Institute until late January, 2001.

Organochlorine contaminants data from 1986 and December 1993 (Muir et al. 1996) were not included in the temporal trend analysis presented in this report because of anomalous results which must first be checked (possibly by re-running the analysis, if the samples can be located).

Results

Mercury, selenium and arsenic

Mean Hg, Se and As concentrations for burbot muscle and liver samples collected between 1985 and 2000 are shown in Tables 1 and 2, respectively. No significant correlation between length and Hg concentration was observed with muscle or liver for either sex. In males, mean Hg concentrations in muscle increased by 36% over the 15-year time period from 1985 to 2000 (Figure 1). For Se, weak negative correlations exist between concentration and length for liver and muscle in male fish. The length-adjusted mean Se concentrations in liver (ANCOVA) were 1.625, 1.156, 0.917 and 1.520 $\mu g \cdot g^{-1}$ for the 1985, 1988, 1999 and 2000 time points, respectively. Arsenic levels in the 1988 male burbot liver samples are significantly higher than those from the 1993, 1999 and 2000 ($p < 0.05$). The highest measured As concentration, 17.16 $\mu g \cdot g^{-1}$, occurred in a muscle sample from a female burbot collected in 1999.

Organohalogens

Table 3 lists the mean concentrations for individual OCs and major OC groups and summarizes the ANCOVA results used to assess the effects of year-to-year collections (temporal trends), percent lipid and lipid*year interactions (homogeneity of the slope between percent lipid and OC concentration) of OCs in burbot liver samples collected from Fort Good Hope in 1988 and 1999.

Significant declines, 2.0- fold and 3.1-fold, were observed for both α- and γ-HCH over this 11-year time period. β-HCH concentrations were below the detection limit in all samples. Interestingly, the α/γ-HCH ratio has increased from 4.5 to 6.9 which is opposite to what one might have expected based on the decreased usage of the technical mixture (α-HCH [60% to 70%], β-HCH [5% to 12%] and γ-HCH [10% to 15%]) and the corresponding increase in the usage of lindane since the early 1990s (Li et al. 1997). The most plausible explanation for this result is that γ-HCH is being transformed by sunlight into α-HCH during long-range transport (Muir et al. 2000, Barrie et al. 1992, Oehme 1991). γ-HCH was reported to be declining at a

Table 1. Mean (standard deviation) concentrations ($\mu g \cdot g^{-1}$) of mercury, selenium and arsenic in burbot muscle from Fort Good Hope

Collection	Sex	n	Length	Hg	Se	As
Apr-85[1]	M	10	633 (84)	0.222 (0.035)a[2]	0.358 (0.087)a	—
Dec-93	M	7	677 (109)	0.231 (0.113)ab	0.534 (0.163)bc	2.291 (3.151)a
Sept-95	M	2	—	0.265 (0.035)abc	—	—
Dec-99	M	21	676 (107)	0.286 (0.095)bc	0.395 (0.107)a	0.637 (0.637)a
Dec-00	M	21	699 (104)	0.345 (0.097)c	0.478 (0.136)c	1.333 (1.944)a
Apr-85[1]	F	6	714 (140)	0.337 (0.136)ab	0.480 (0.126)ad	—
Dec-93	F	3	812 (133)	0.297 (0.035)ab	0.321 (0.009)b	6.450 (0.984)a
Sept-95	F	2	—	0.180 (0.085)ab	—	—
Dec-99	F	21	735 (101)	0.259 (0.108)a	0.219 (0.104)c[3]	2.626 (3.815)b
Dec-00	F	15	732 (127)	0.364 (0.140)b	0.460 (0.175)d	1.929 (1.621)b

[1] Wagemann 1985

[2] Data in the same column followed by a different letter differ significantly by *t*-test ($p < 0.05$).

[3] $n = 20$

Table 2. Mean (standard deviation) concentrations ($\mu g \cdot g^{-1}$) of mercury, selenium and arsenic in burbot liver from Fort Good Hope

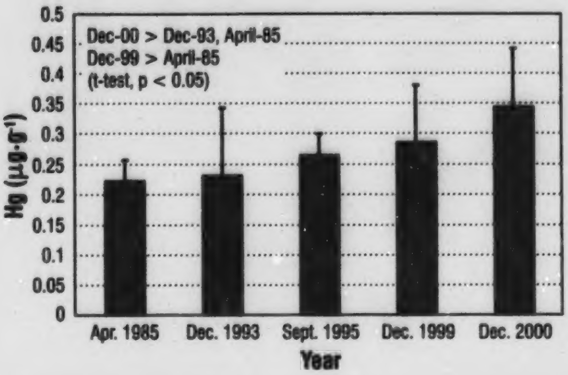
Collection	Sex	n	Length	Hg	Se	As
Apr-85[1]	M	9	643 (82)	0.044 (0.019)a[2]	1.759 (0.558)a	—
Dec-88	M	8	706 (84)	0.054 (0.026)ab	1.230 (0.555)bc	3.119 (1.725)a
Dec-93	M	7	677 (109)	—	—	1.016 (1.328)b
Dec-99	M	21	676 (107)	0.046 (0.024)a	1.071 (0.628)b[3]	0.607 (0.326)b
Dec-00	M	21	699 (104)	0.064 (0.026)b	1.646 (0.733)ac	0.585 (0.412)b
Apr-85[1]	F	6	714 (140)	0.097 (0.098)a	1.272 (0.715)a	—
Dec-88	F	2	623 (86)	0.072 (0.035)a	1.460 (1.529)a	1.280 (1.018)ab
Dec-93	F	3	812 (129)	—	—	1.062 (0.546)ab
Dec-99	F	20	749 (77)	0.064 (0.069)a	0.687 (0.552)b[3]	1.353 (0.811)a
Dec-00	F	15	732 (127)	0.094 (0.056)a	1.203 (0.469)a	0.632 (0.349)b

[1] Wagemann 1985

[2] Data in the same column followed by a different letter differ significantly by *t*-test ($p < 0.05$).

[3] $n = 19$

Figure 1. Mean Hg concentrations ($\mu g \cdot g^{-1}$) in muscle samples from male burbot from Fort Good Hope, NWT



faster rate than α-HCH in air samples collected at Alert, Nunavut, from January 1993 to December 1997 (Blanchard 2000).

ΣDDT concentrations did not change over this 11-year time interval; however, a 1.8-fold decline and a 2.2-fold increase in the concentration of *p,p'*-DDT and its metabolite *p,p'*-DDE (not age adjusted), respectively, was observed. These changes translated into a significant increase in the *p,p'*-DDE/ΣDDT ratio from 0.39 to 0.60 and suggests "old" rather than recent DDT inputs.

Overall, a 1.7-fold decline in the lipid adjusted mean concentrations of ΣCHL was observed. Oxychlordane, the principal metabolite of *cis*- and *trans*-chlordane, and second only to *trans*-nonachlor as the most abundant chlordane-related residue in the Fort Good Hope burbot liver, did not change significantly over this 11-year period. The decreasing *t/c*-CHL ratio suggests "old" rather than recent chlordane inputs. For *t*-nonachlor, lipid-year interactions (lipid*year) were significant ($p > 0.05$) and as a result, ANCOVA could not be used to correct for the observed effects from lipid (homogeneity of the slope between percent lipid and *t*-nonachlor concentration). While heptachlor concentrations in the burbot liver have decreased by 2.3-fold over this 11-year time period, the level of its oxidation product, heptachlor epoxide, increased by 1.9-fold.

ΣTri-PCB concentrations have increased by 2.9-fold, while all other PCB homologue groups have either declined in concentration or did not change significantly. ΣPCB levels have declined by 1.3-fold. No significant differences were observed for *n*PCB 77, 81 or 169. CB126 decreased by 1.8-fold. ΣCHB and dieldrin concentrations have decreased by 1.7- and 1.5-fold, respectively.

Major PBDE congener and homologue concentrations in selected burbot liver samples are listed in Tables 4a and 4b. PBDE47 is the most predominant PBDE congener residue in the burbot liver followed by PBDE99, 100, 153 and 154. A similar profile was observed in Pangnirtung beluga (Stern and Ikonomou 2000b, Stern and Ikonomou 2000c). In comparison, Jansson et al. (1993) reported mean BDPE47 and 99 concentrations of 99 and 31 $pg \cdot g^{-1}$ (wet weight) in whitefish muscle from Lake Storvindeln and 21200 and 3392 $pg \cdot g^{-1}$ (wet wt) in Arctic char from Lake Vattern, Sweden.

Discussion and Conclusions

Muscle and liver samples from burbot collected at Fort Good Hope (Rampart Rapids) in 2000 were analyzed for Hg, Se and As. These data, combined with the existing data from 1985, 1993 and 1999, cover a time span of 15 years. No significant correlation between length and Hg concentration was observed with muscle or liver for either sex. In the males, mean Hg concentrations in muscle increased by 36% over the 15-year time period from 1985 to 2000. Mean Hg concentrations in muscle and liver over the entire data sets were 0.295 ± 0.112 ($n = 108$) and 0.064 ± 0.049 ($n = 102$) $\mu g \cdot g^{-1}$, respectively. Muscle Hg levels are below the recommended guideline level of 0.50 $\mu g \cdot g^{-1}$ for commercial sale but are at, or exceed, the guideline level of 0.2 $\mu g \cdot g^{-1}$ recommended for fish used for subsistence. Liver and muscle concentrations of Se declined with increasing fish length. A similar correlation has been observed for Atlantic cod (Stange et al. 1996). As was observed in fish from other lakes in the Northwest Territories (Lockhart et al. 2000), no statistical correlation was observed between Hg and Se.

Organohalogen analysis in the burbot liver from the 2000 collection are currently underway. Additional burbot collections from Fort Good Hope (Rampart Rapids) are planned for December 2001 and 2002, as well as 2003 and 2004, depending on the priorities of Northern Contaminants Program Phase III.

Current results were communicated to the residents of Fort Good Hope during a visit made by G. Stern and G. Low on March 29, 2001.

Expected Project Completion Date

Temporal trend studies are long-term and thus annual sampling is projected until at least 2005 (eight time points covering 17 years for the organohalogen compounds and 10 time points covering 21 years for Hg).

Table 3. Means (standard deviation) and summary of ANCOVA results used to assess the effects of year to year collections (temporal trends), % lipid and lipid*year interactions (homogeneity of the slope between % lipid and [OC]) of OCs in burbot liver from Fort Good Hope[1]

	Mean (SD)		% Lipid (Pr)	Lipid*year (Pr)	r^2 (model)	Lipid adjusted mean		Factor
	1988	1999				1988	1999	
HCBz	13.07 (4.06)	5.43 (2.17)	< 0.0001	0.0240	0.95	—	—	—
ΣCBz	13.63 (4.21)	10.04 (3.81)	< 0.0001	0.0886	0.88	16.51	8.18	2.01↓
α-HCH	4.55 (1.40)	3.16 (1.16)	< 0.0001	0.6499	0.78	5.36	2.63	2.03↓
γ-HCH	0.98 (0.31)	0.46 (0.17)	< 0.0001	0.4320	0.87	1.18	0.38	3.11↓
α/γ-HCH[2]	4.65 (0.14)	6.89 (0.70)	0.0356	0.3070	0.81	4.51	6.95	1.54↑
ΣHCH	5.53 (1.71)	3.78 (1.38)	< 0.0001	0.6154	0.79	6.53	3.15	2.07↓
trans-CHL	0.65 (0.20)	0.16 (0.06)	0.0372	0.2425	0.92	0.79	0.13	3.08↓
cis-CHL	0.65 (0.21)	0.52 (0.21)	< 0.0001	0.1995	0.86	0.79	0.42	1.88↓
trans-Nona	11.18 (3.47)	11.16 (4.36)	< 0.0001	0.0383	0.89	—	—	—
Oxychlor	2.68 (0.87)	3.65 (1.47)	< 0.0001	0.1152	0.84	3.29	2.90	1.13
t/c-CHL1	1.00 (0.05)	0.30 (0.05)	< 0.0001	0.5039	0.98	1.00	0.30	3.33↓
ΣCHL	23.83 (7.37)	21.00 (8.04)	< 0.0001	0.0841	0.87	28.94	17.07	1.70↓
Heptachlor	0.23 (0.07)	0.15 (0.06)	< 0.0001	0.3826	0.80	0.28	0.12	2.33↓
H. Epoxide	1.07 (0.32)	2.96 (1.10)	< 0.0001	0.3025	0.89	1.28	2.43	1.90↑
o,p'-DDE	0.63 (0.21)	0.43 (0.15)	< 0.0001	0.5053	0.83	0.75	0.35	2.14↓
p,p'-DDE	6.23 (2.00)	13.66 (5.35)	< 0.0001	0.0299	0.95	—	—	—
o,p'-DDD	0.31 (0.11)	0.69 (0.27)	< 0.0001	0.5265	0.88	0.37	0.94	2.54↑
p,p'-DDD	1.46 (0.45)	3.20 (1.20)	< 0.0001	0.2589	0.88	1.76	2.60	1.48↑
o,p'-DDT	4.46 (1.39)	2.33 (0.87)	< 0.0001	0.3884	0.86	5.33	1.91	2.79↓
p,p'-DDT	3.08 (1.13)	2.53 (0.94)	< 0.0001	0.4679	0.78	3.64	2.07	1.76↓
p,p'-DDE/ΣDDT[2]	0.39 (0.01)	0.60 (0.03)	< 0.0001	0.5610	0.93	0.39	0.60	1.54↑
ΣDDT	16.17 (5.25)	22.84 (8.59)	< 0.0001	0.1160	0.89	19.51	18.68	1.04
ΣMono/Di-PCB	2.32 (0.82)	3.00 (1.06)	< 0.0001	0.6827	0.82	2.76	2.47	1.12
ΣTri-PCB	1.65 (0.53)	6.81 (2.43)	< 0.0001	0.4191	0.95	1.97	5.62	2.85↑
ΣTetra-PCB	7.57 (2.34)	7.32 (2.63)	< 0.0001	0.2797	0.81	9.08	6.03	1.51↓
ΣPenta-PCB	21.38 (6.73)	14.82 (5.28)	< 0.0001	0.3204	0.85	25.60	12.21	2.10↓
ΣHexa-PCB	19.76 (6.28)	25.33 (8.96)	< 0.0001	0.3719	0.82	23.64	20.87	1.13
ΣHepta-PCB	4.84 (1.57)	4.79 (1.73)	< 0.0001	0.3826	0.83	5.80	3.94	1.47↓
ΣOcta-PCB	0.33 (0.13)	0.57 (0.22)	< 0.0001	0.7957	0.84	0.39	0.46	1.18
ΣNona-PCB	0.27 (0.09)	0.14 (0.05)	< 0.0001	0.5946	0.86	0.32	0.11	2.90↓
ΣPCB	58.10(18.45)	62.77(22.29)	< 0.0001	0.3589	0.82	69.53	51.73	1.34↓
ΣCHB	60.83(19.31)	54.03(20.37)	< 0.0001	0.1424	0.85	73.81	43.83	1.68↓
Dieldrin	2.38 (0.74)	2.38 (0.93)	< 0.0001	0.1285	0.83	2.89	1.92	1.51↓
*n*PCB 77	11.37 (5.32)	13.97(10.61)	0.0003	0.9882	0.43	12.43	10.38	1.20
*n*PCB 81	0.58 (0.34)	0.61 (0.44)	< 0.0001	0.6445	0.49	0.60	0.47	1.28
*n*PCB 126	10.33 (3.63)	7.32 (4.94)	0.0289	0.6971	0.19	10.70	5.90	1.81↓
*n*PCB 169	22.73(11.32)	22.26(15.76)	0.0308	0.8360	0.18	17.54	18.86	0.93

[1] All concentrations are in $ng \cdot g^{-1}$ with the exception of nPCBs ($pg \cdot g^{-1}$).

[2] Ratios were not log transformed; significant increase (↑) or decrease (↓) in the adjusted means of individual OCs and groups ($p < 0.05$).

Table 4a. Major PBDE congener concentrations ($pg{\cdot}g^{-1}$, wet wt.) in burbot liver from Fort Good Hope (collected December 1999)

Sample	Age	Length	% Lipid	47[1]	99[2]	100[3]	153[4]	154[5]
BL1-99	19	910	23.6	1311.0	519.8	362.4	299.6	264.5
BL2-99	11	818	30.8	612.6	673.9	319.1	127.5	251.2
BL3-99	13	844	41.0	196.4	157.4	78.4	nd	67.8
BL4-99	12	814	44.6	211.3	129.0	71.0	56.9	46.4
Mean	14	847	35.0	582.8	370.0	207.7	161.3	157.5
SD	4	44	9.6	522.3	269.6	154.7	124.8	116.4

[1] 2, 2', 4, 4'-TeBDE

[2] 2, 2', 4, 4', 5-PeBDE

[3] 2, 2', 4, 4', 6-PeBDE

[4] 2, 2', 4, 4', 5, 5'-HxBDE

[5] 2, 2', 4, 4', 5, 6'-HxBDE

Table 4b. Major PBDE homologue concentrations ($pg{\cdot}g^{-1}$, wet wt.) in burbot liver from Fort Good Hope (collected December 1999)

Sample	Age	Length	% Lipid	TrBDE	TeBDE	PeBDE	HxBDE	HpBDE	ΣPBDE
BL1-99	19	910	23.6	19.2	1332.6	930.8	608.0	4.4	2895.0
BL2-99	11	818	30.8	9.5	698.2	1088.2	399.6	0.9	2196.4
BL3-99	13	844	41.0	7.4	231.8	307.0	82.1	nd	628.3
BL4-99	12	814	44.6	9.5	246.6	261.1	118.6	nd	635.8
Mean	14	847	35.0	11.4	627.3	646.8	302.1	1.33	1588.9
SD	4	44	9.6	5.3	517.6	424.2	248.4	2.1	1147.1

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Temporal Trends of Organohalogen Compounds in Canadian Arctic Beluga

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Abstract

Archived blubber samples from male western Arctic beluga (Eskimo Lakes 1989, Hendrickson Island 1995 were analyzed for *n*PCBs and PBDEs (polybrominated diphenyl ethers). Over the 6-year period from 1989 to 1995, ΣPBDE and PBDE47 (2,2',4;4'-TeBDE), the most predominant PBDE congener residue in the beluga blubber, increased by 1.3- and 1.5-fold, respectively. In comparison, ΣPBDE and PBDE47 levels increased by 1.8- and 1.9-fold, respectively, in Holman Island ringed seal over the 5-year period from 1991 to 1996, and by 4.1- and 3.7-fold over the 6-year period from 1986-1992 in eastern Arctic beluga from Pangnirtung. These increases reflect the increase in PBDE industrial use world wide. The presence PBDEs in Arctic marine mammals provides additional evidence in support of their ability to be transported long distances through the atmosphere.

Key Project Messages

1. Total PBDEs concentrations in western Arctic beluga have increased by approximately 32% over the 6-year period from 1989 to 1995, similar to recent reports for ringed seal from Holman Island and Pangnirtung beluga (eastern Arctic).
2. The presence of this class of flame retardants in Arctic marine mammals provides additional evidence in support of their ability to be transported long distances through the atmosphere.

Objectives

1. Document the temporal trends of organohalogen contaminants in Arctic marine ecosystems so as to determine whether contaminant levels in marine mammal tissues, and thus exposure to people living

in Arctic communities who consume them as part of their traditional diet, are increasing or decreasing with time.

2. Provide data on contaminant levels in marine mammal tissues as part of surveys of dietary contamination and for use by the Arctic Monitoring and Assessment Programme (AMAP).
3. Equip Canadian delegations involved in international controls with appropriate information to formulate Canadian positions.

Introduction

Marine mammals are harvested by several Inuit communities. These animals occupy high trophic levels in marine food webs and so accumulate relatively high concentrations of persistent organohalogen contaminants. Documentation of temporal trends in the extent of contamination by these compounds will contribute to an exposure risk assessment.

Brominated flame retardants are used in relatively high concentrations in electronic equipment such as computers and television sets, building materials, carpets, cars, aircraft and in many other applications. Polybrominated diphenyl ethers (PBDEs) are used as additive flame retardants (Sellström 1996), which are incorporated into the matrix of various plastic materials such as polystyrenes (Zitko 1993). Over the last 2 decades, the use of brominated flame retardants has increased substantially. In Japan, the annual consumption of brominated organic compounds increased from 2500 tonnes in 1975 to 22 100 tonnes in 1987 (Watanabe and Tatssukawa 1989). From 1984 to 1992, the total consumption of PBDEs world-wide doubled from approximately 20 000 to 40 000 tonnes per year. Presently, the word-wide consumption of brominated flame retardant is estimated to be 150 000 tonnes per year (Sellström and Jansson 1995, Jansson et al 1993, Sellström 1996, Zitko 1993). As a result, PBDEs have been released into the environment to such an extent that they are now ubiquitous environmental contaminants.

PBDEs are similar in behaviour and toxicity to well-known environmental contaminants such as polychlorinated biphenyls (PCBs) and DDT, but have not been banned to date. Because of their high lipophilicity (log $K_{ow} > 5$, where K_{ow} is the octanol-water partition coefficient) and resistance to degradative processes, PBDEs are expected to bioaccumulate easily (Pijnenburg et al. 1995, de Boer et al. 1998, de Boer et al. 2000). PBDEs have been detected at the parts per billion levels (lipid wt) in fish, fish-eating birds and marine mammals from remote areas (Pijnenburg et al. 1995, Jansson et al. 1987, Watanabe et al. 1987, de Boer 1989, de Boer et al. 1998, de Boer et al. 2000, Kuehl et al. 1991, Sellström et al. 1993, Loganathan et al. 1995, Haglund et al. 1997), but limited information is available in Arctic marine mammals. Recently, Stern et al. (2000a, 2000b) and Ikonomou et al. (2000) reported 6.8- and 5.7-fold increases of ΣPBDEs in blubber samples from Pangnirtung beluga (1982-1997) and Holman Island ringed seal (1981-1996), respectively.

Activities in 2000-2001

Archived blubber samples from male western Arctic beluga (Eskimo Lakes 1989, Hendrickson Island 1995) were analyzed for *n*PCBs and PBDEs. In addition, all Eskimo Lake samples and 10 archived samples of blubbers from male beluga collected at East Whitefish (1993), were analyzed for organochlorine pesticides (OCs) and PCBs. OC and PCB data for the Hendrickson Island animals was provided by D. Muir.

Blubber samples from 24 male Hendrickson Island beluga were collected in July 2000. Unfortunately, as a result of a storm of unprecedented strength, which hit on August 7, all the jaws from the collection were lost. Because of the high cost of analysis, and the importance of the age data, it was decided that we should not proceed any further and that the collection should be repeated in 2001.

Collections

All samples were obtained by Department of Fisheries and Oceans personnel (Winnipeg, MB) with the cooperation of local hunters. Blubber, kidney, liver, ovaries and uterus, muscle and the lower jaw, as well as morphometric data, were collected for each animal. All samples were shipped frozen to the Freshwater Institute and stored at –30°C until analysis. Animals were aged by thin sectioning a canine tooth from the rear of the lower jaw and counting growth layer groups in the dentine using transmitted light (Heide-Jrrgensen et al. 1994).

Analysis

Samples of beluga blubber were analyzed for 130 individual OC contaminants (90 PCB congeners and 40 other OC pesticides) as described by Muir et al. (1990). In brief, 2 g of each blubber sample was combined with anhydrous sodium sulfate (heated at 600°C) for 16 hours prior to use. The mixture was then extracted twice with 50 mL of hexane using a ball mill, centrifuging and decanting the hexane between extractions. Surrogate recovery standards of CB30 and octachloronaphthalene were added prior to extraction. Extractable lipids were determined gravimetrically on one-tenth of the extract. A portion of the extract equivalent to approximately

100 mg was then separated into three fractions of increasing polarity on a Florisil column (8 g, 1.2% H_2O deactivated). The first fraction was eluted with hexane and contained PCBs, *p,p'*-DDE, chlorobenzenes, mirex, and a small portion of CHBs (toxaphene), most notably T2/B8-1413 (Stern et al. 1992, Andrews and Vetter 1995). Fraction two was eluted with hexane:DCM (85:15) and contained HCHs, chlordanes, and the remainder of the DDT and CHB congeners. The final fraction was eluted with a 1:1 mixture of hexane:DCM. Each of the three fractions were then analyzed by high resolution gas chromatography with electron capture detection using a 60 m x 0.25 mm DB-5 capillary column (0.25 µm film thickness) with hydrogen carrier gas. Total PCB (ΣPCB) corresponds to the sum of all congeners. Total chlordane (ΣCHL) to the sum of all chlordane related compounds and DDT (ΣDDT) to the sum of *p,p'*-DDE, *o,p'*-DDE, *p,p'*-DDD, *o,p'*-DDD, *p,p'*-DDT and *o,p'*-DDT. Toxaphene (ΣCHB) was quantified using a single response factor based on 27 peaks in the technical mixture. Approximately 75% to 80% of ΣCHB in beluga blubber is ascribed to two individual congeners, an octa- and nonachlorobornane, referred to as T2 (Parlar#26, B8-1413) and T12 (Parlar#50, B9-1679) (Stern et al. 1992, Andrews and Vetter 1995). Approximately, 1 g of each sample extract was sent to Institute of Ocean Sciences for *n*PCB and PBDE analysis. Samples were spiked with a suite of internal standards and processed for GC/HRMS analysis using the methodology described by Ikonomou et al. (1998, 1999). Quantitation was based on custom standard solutions prepared by Cambridge Isotope Laboratories.

Statistical analysis

All univariate analyses were performed with lipid normalized $\log_{10}$ transformed data to adjust for skewness. Analysis of covariance (ANCOVA) was used to assess the effects of year-to-year collections (temporal trends), location (Hendrickson Island and Pangnirtung), age of the animals, age*year and age*location interactions (homogeneity of slope between age and [organohalogen]) using the models

[organohalogen] = year age age*year

and

[organohalogen] = age location age*location

where [organohalogen] = log concentration of individual congeners and homologue groups.

Differences between collection years and locations were examined with paired comparisons of age adjusted mean concentrations (SAS Institute 1989-1996). Only results for animals > 2 years of age were included in the analysis of covariance because of the large variations in concentrations seen in younger animals (Stern et al. 1994).

Results

Temporal trends of lipid normalized (age-adjusted) *n*PCBs, PBDE homologue group and congener concentrations are shown in Table 1. Over the 6-year period from 1989 to 1995, the levels of the PeBDE and HxBDE homologue groups and all major congeners in the western Arctic beluga have increased significantly. Increases ranged from 1.5-fold for PBDE47 (2,2',4,4'-TeBDE), the most predominant PBDE congener residue in the beluga blubber, to 5.7-fold for BDE153. Overall, ΣPBDE concentrations increased by 1.3-fold. Coplanar PCB congeners CB80, CB126 and CB169 declined in concentration by 2.0-, 3.3- and 3.6-fold, respectively. Accordingly, *n*PCB toxic equivalences (TEQs) have also declined (e.g. CB126 has declined from 19.09 to 5.76 $pg \cdot g^{-1}$). No significant differences were observed between the concentrations of major OC groups (e.g. DDT, toxaphene, CHL, PCB homologues) in male blubber samples collected from animals at Eskimo Lakes (1989), Hendrickson Island (1993-1995) and East Whitefish (1993).

Measured increases of PBDEs in blubber samples from male Holman Island Ringed seal (western Arctic), Pangnirtung beluga (eastern Arctic), Hendrickson and Eskimo Lake beluga (western Arctic) over comparable time periods are shown in Table 2. Similar increases were observed for both the Holman ringed seal and the western Arctic beluga. In the Pangnirtung beluga, the greatest increase in PBDE levels occurred over the 6 years between 1986-1992. With the exception of congeners BDE99, BDE154 and HxBDE, no significant differences were observed between PBDE concentrations in the eastern (1997 collection) and western (1995 collection) Arctic animals (Table 3).

Discussion and Conclusions

This report provides additional temporal trend data on PBDEs in Arctic marine mammals. Total PBDEs concentrations in western Arctic beluga, as has recently been reported for ringed seal from Holman Island and Pangnirtung beluga (eastern Arctic), have increased by approximately 32% over the 6-year period from 1989 to 1995.

The presence of this class of flame retardants in Arctic marine mammals provides additional evidence in support of their ability to be transported long distances through the atmosphere. This and the observed increasing trends are of great concern and call for measures to further regulate usage of PBDEs.

Future work will involve increasing the time series of the western Arctic beluga (1989, 1995, 2001), Pangnirtung beluga (1982, 1986, 1992, 1997, 2001), Sanikiluaq beluga (1994, 1998 and 2002) and Holman Island ringed seal (1981, 1991, 1996, 2000) collections.

Expected Project Completion Date

This project is ongoing

Table 1. Means (standard deviation) and summary of ANCOVA results used to assess the effects of year to year collections (temporal trends), age and age*year interactions (homogeneity of the slope between age and [organohalogen]) on PBDE and *n*PCB contaminant levels in blubber from male western Arctic beluga

	Mean (SD) ($pg \cdot g^{-1}$)					Age adjusted mean ($pg \cdot g^{-1}$)		
	1989	1995	Age (Pr)	Age*year (Pr)	R^2 (model)	1989	1995	Factor
Age[1]	14.3 (7.7)	15.3 (4.8)	—	—	—	—	—	—
BDE47	5814.6 (2261.2)	8764.2 (2452.6)	0.5539	0.8791	0.29	6061.2	9103.0	1.50↑
BDE49	3452.6 (1531.3)	3117.8 (1609.7)	0.0513	0.2390	0.24	3556.0	2937.6	1.21
BDE99	594.5 (266.3)	1032.9 (281.6)	0.8735	0.5817	0.38	597.7	1079.8	1.81↑
BDE100	603.3 (228.7)	1135.1 (300.9)	0.7068	0.9669	0.51	623.6	1195.8	1.92↑
BDE119	8.1 (2.8)	19.7 (8.8)	0.0060	0.3378	0.72	8.3	19.8	2.40↑
BDE153	28.2 (18.6)	118.4 (41.4)	0.4313	0.8691	0.58	21.7	123.6	5.70↑
BDE154	109.6 (42.5)	381.4 (109.0)	0.1674	0.5098	0.83	112.2	403.4	3.60↑
TrBDE	231.7 (98.8)	276.3 (76.5)	0.0748	0.9593	0.24	232.6	291.1	1.25
TeBDE	10 111.8 (3941.5)	12 476.4 (3912.4)	0.2416	0.8026	0.15	10 566.0	12 834.9	1.20
PeBDE	1207.0 (489.4)	2188.3 (566.9)	0.8773	0.7945	0.46	1238.1	2303.8	1.86↑
HxBDE	165.3 (69.4)	594.1 (179.1)	0.2448	0.4989	0.81	166.4	625.5	3.76↑
SPBDE	11 715.7(4435.2)	15 535.1 (4400.9)	0.3638	0.9317	0.20	12 268.6	16 147.3	1.32↑
Age[1]	15.5 (7.1)	15.7 (5.8)	—	—	—	—	—	—
*n*PCB 80	175.1 (107.5)	94.6 (61.4)	0.3128	0.6312	0.26	162.1	80.1	2.00↓
*n*PCB 81	10.4 (9.2)	8.14 (3.3)	0.3841	0.9183	0.05	8.96	8.1	1.11
*n*PCB 126	222.6 (127.8)	62.1 (41.4)	0.2765	0.2351	0.45	190.9	57.6	3.31↓
*n*PCB 169	1282.0 (1071.3)	314.2 (215.8)	0.0177	0.3383	0.59	1027.3	286.1	3.59↓

[1] Twelve and 15 samples were analyzed from each of the 1989 and 1995 collection, respectively. However, nPCB and PBDE analyses are currently being repeated on certain samples because of poor analytical results; thus, the difference in the mean ages between the collection year and contaminants group: significant increase (↑) or decrease (↓) in the adjusted means of individual congeners and groups ($p < 0.05$).

Table 2. Factor increases of major PBDE homologues and congeners over selected time periods for eastern (Pangnirtung) and western Arctic (Eskimo Lakes and Hendrickson Island) beluga and Holman Island (western Arctic) ringed seal[1]

	Western Arctic beluga	Eastern Arctic beluga[2]			Holman ringed seal[3]
	1989-95	1982-1986	1986-1992	1992-1997	1991-96
BDE47	*1.5*	*1.6*	*3.7*	1.1	1.9
BDE99	*1.8*	1.6	*6.9*	0.9	1.9
BDE100	*1.9*	1.5	*4.8*	1.1	2.0
BDE154	*3.6*	*2.1*	*14.1*	1.1	1.9
TrBDE	1.3	1.1	*2.1*	0.9	1.2
TeBDE	1.2	*1.6*	*3.7*	1.1	1.8
PeBDE	*1.9*	1.5	*5.2*	1.1	1.9
HxBDE	*3.8*	*3.0*	*13.6*	1.1	1.9
ΣPBDE	***1.3***	**1.5**	***4.1***	**1.1**	**1.8**

[1] Italicized numbers indicate that the age adjusted mean concentration differences were significant by *t*-test at $p < 0.05$ (beluga only).

[2] Source: Stern and Ikonomou 2000a

[3] Source: Ikonomou et al. 2000

Table 3. Means (standard deviation) and summary of ANCOVA results used to assess the effects of location, age and age*location interactions (homogeneity of the slope between age and [PBDE]) on PBDE levels in blubber from male eastern (Pangnirtung) and western (Hendrickson Island) Arctic beluga

	Mean (SD) ($pg \cdot g^{-1}$)					Age adjusted mean ($pg \cdot g^{-1}$)		
	West[1]	East[2]	Age (Pr)	Age*loc (Pr)	R^2 (model)	West	East	Factor[3]
Age	15.3 (4.8)	14.3 (5.1)	—	—	—	—	—	—
BDE47	8764.2 (2452.6)	9470.1 (2360.2)	0.3585	0.2717	0.07	9186.4	10 130.9	1.10
BDE99	1032.9 (281.6)	685.6 (338.2)	0.0061	0.1379	0.53	1108.0	687.3	0.61W
BDE100	1135.1 (300.9)	1419.7 (492.4)	0.0109	0.1707	0.33	1213.0	1471.1	1.21
BDE154	381.4 (109.0)	794.4 (596.8)	0.0002	0.1675	0.59	415.7	697.2	1.68 E
TrBDE	276.3 (76.5)	532.0 (154.2)	0.9992	0.0589	0.57	—	—	—
TeBDE	12 476.4 (3912.4)	10 056.8 (2407.6)	0.8493	0.1539	0.10	12 972.7	10 811.2	0.83
PeBDE	2188.3 (566.9)	2180.2 (818.4)	0.0060	0.1602	0.31	2346.2	2250.2	0.96
HxBDE	594.1 (179.1)	1247.8 (982.9)	0.0016	0.3476	0.48	643.2	1061.3	1.65 E
ΣPBDE	15 535.1 (4400.9)	14 016.8 (3707.5)	0.2892	0.1241	0.08	16 369.9	14 950.3	0.91

[1] 1995 collection ($n = 9$)

[2] 1997 collection ($n = 15$)

[3] Age adjusted mean concentrations significantly higher ($p < 0.05$) in the eastern Arctic (E) and western (W) Arctic animals

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Temporal and Spatial Trends of Mercury in Fish from Yukon Lakes and in Sediment Cores from Lake Laberge

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Abstract

Length adjusted mean concentrations of mercury in lake trout (muscle) from Lake Laberge have decreased by ~30% between 1993 and 1996, while no significant change was observed between 1996 and 1998. In comparison, no significant differences were observed in the mercury concentrations measured in lake trout muscle samples collected from Quiet Lake in 1992 and 1999. Of the four lakes included in this study, Kusawa Lake lake trout muscle had the highest mercury concentrations followed by those from Lake Laberge and Quiet Lake. In burbot liver, the Lake Laberge fish had slightly higher mercury concentrations than did the fish from Kusawa, Fox and Quiet Lakes.

In March 2000, three sediment cores were collected from the north, central and southern areas of Lake Laberge. The mean mercury flux, over the period from ~1950-1999, ranged from 34.4 to 46.0 $\mu g \cdot m^{-2} \cdot y^{-1}$. Historical fluxes, calculated from core slices dated to the pre-1800s, ranged from 30.4 to 41.7 $\mu g \cdot m^{-2} \cdot y^{-1}$. In both recent and historical times, the influence of the Yukon River as a source of mercury to the lake sediments decreases in a northerly direction along the lake. Anthropogenic input of mercury to the lake sediments, recent minus historical fluxes, averaged 4.3 $\mu g \cdot m^{-2} \cdot y^{-1}$. An interesting aspect observed in all three cores is the measured drop in mercury concentrations in the late-1880s, early-1900s, and again in the early-1930s. The fact that each of the three cores records the same historical declines in mercury deposition to the lake sediment, whatever the causes may be, is good evidence that the fidelity of the cores are not substantially affected by processes such as biomixing and mercury remobilization.

Key Project Messages

1. In lake trout muscle from Lake Laberge, a 30% decline in mercury (Hg) concentrations was measured from 1993-1996; no change was measured from 1996-1998. In comparison, no significant differences in Hg levels were observed in lake trout from Quiet Lake over the 7-year period from 1992 to 1999.
2. Among the four Yukon lakes sampled, lake trout muscle from Kusawa Lake had the highest Hg concentrations, followed by Lake Laberge and Quiet Lake.
3. All lake trout muscle samples from Kusawa Lake exceeded the guideline level of 0.20 $\mu g \cdot g^{-1}$ recommended for fish used for subsistence, while 36% of the samples had concentrations at or above the recommended guideline level of 0.50 $\mu g \cdot g^{-1}$. The highest concentration measured (1.8 $\mu g \cdot g^{-1}$) was in an old male (> 30 years) and was almost four-fold higher than the subsistence recommended guideline.
4. Inputs of Hg to Lake Laberge sediments through human activities averaged 4.3 $\mu g \cdot m^{-2} \cdot y^{-1}$.
5. In both recent and historical times, the influence of the Yukon River as a source of Hg to Lake Laberge sediments decreases in a northerly direction along the lake.

Objectives

1. Document the temporal and spatial trends of Hg in fishes from Yukon lakes, so as to determine whether contaminant levels in the fish and thus exposure to people, who consume them, are increasing or decreasing with time.
2. Determine the down core profiles of Hg in sediment cores from three separate locations in Lake Laberge and to calculate the modern and historic flux of Hg to the lake.
3. Determine the underlying factor(s) responsible for the observed decline of Hg concentrations in Lake Laberge fish.

Introduction

Several independent lines of evidence suggest that inputs of Hg to northern Canada have increased over pre-industrial levels. With a few exceptions, minimal or no direct temporal trend information on Hg is available in biota from either the Arctic marine or freshwater environments. The Northern Contaminants Program has noted this as a significant knowledge gap. Mercury in Arctic seals and whales has increased since the 1970s (Wagemann et al. 1996). More recently, Stern et al. (2000, 2001) have reported that Hg levels in burbot muscle from Fort Good Hope, on the Mackenzie River, have increased by 36% over the 15-year period 1985-2000. Muir et al. (2000) reported no significant changes in Hg concentrations in Arctic char from Resolute and Char Lakes over the 7-year period 1992-1999.

Since 1991, fish have been sampled from lakes and rivers throughout the Yukon (Palmer 1999). Many of these tissues have been archived and are available for chemical analysis and inclusion as part of a temporal trend study. Lake trout and burbot were chosen as indicator species because they are consumed as traditional/country foods and are top trophic level feeders. Kusawa, Laberge and Quiet Lakes were selected for the temporal trend study (Palmer 1999) and recent collections have been made to supplement those available from earlier collections.

A temporal trend study of contaminants in fish from Lake Laberge is of particular interest because of the unusually high organochlorine (OC) contaminants levels found in the lake trout (muscle) and burbot (liver) in 1991. Kidd et al. (1993, 1995) attributed the elevated concentrations to heavy fishing pressure that altered the foodweb structure of the lake. DeGraff and Mychasiw (1994) suggested that rehabilitation of the lake trout stock in Lake Laberge, due to reduced fishing pressure, should restore the predator:prey balance to a level comparable with other regional lakes, and cause a decline in contaminant levels. As a result of the closure of the fishery, lake trout abundance in Lake Laberge has almost doubled. Stern et al. (2000, 2001) recently reported a decline in OC concentrations in both lake trout and burbot liver; the results for Hg are presented here.

Mercury can have natural, geological sources within a watershed, but it can also be deposited as a result of human activities that release Hg into the air or water. Analysis of the sediment cores from various locations in Lake Laberge will allow us to estimate the extent of anthropogenic inputs of Hg to the lake and compare those inputs with natural ones.

Activities in 2000-2001

Lake trout and burbot were collected from Kusawa, Laberge and Quiet Lakes in 2000, and the analysis of recent and archived collections for organic and trace metal contaminants continued. Sediment cores were collected from Lake Laberge and analyzed for trace metals.

Results and Discussion

Fish

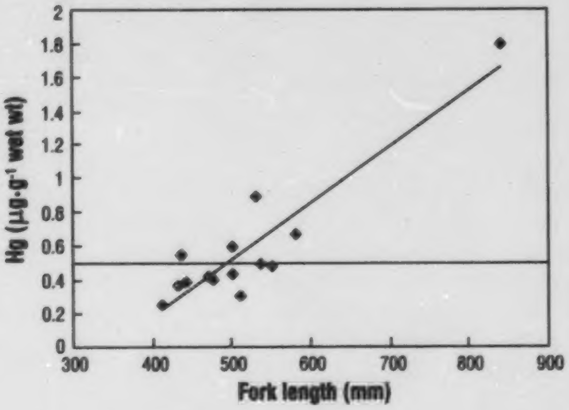
Mean and length adjusted mean (ANCOVA) Hg concentrations in Lake Laberge lake trout muscle and burbot liver are shown in Table 1. In both tissues, Hg concentrations are significantly positively correlated with fish length. Length adjusted concentrations in lake trout muscle decreased by ~30% between 1993 and 1996 while no significant change was observed between 1996 and 1998. Similarly, no change was observed in burbot liver Hg levels between 1996 and 1999. Whereas 97% of all the lake trout muscle samples (1993-1998) had Hg concentrations that exceeded the guideline level of 0.20 $\mu g{\cdot}g^{-1}$ recommended for fish used for subsistence, 71% of the lake trout ≥ 500 mm in length had concentrations at or above the guideline level of 0.50 $\mu g{\cdot}g^{-1}$ recommended for commercial fisheries.

No significant differences were observed in the mean and length adjusted mean Hg concentrations measured in lake trout muscle samples collected from Quiet Lake in 1992 (n = 5) and 1999 (n = 9). An additional 17 lake trout muscle samples collected in 1992 from Quiet Lake and 15 from Kusawa Lake in 1993 are currently being analyzed for Hg but the data are not yet available.

Figure 1 shows the muscle Hg concentrations in lake trout of varying length collected from Kusawa Lake in 1999. All samples exceeded the guideline level of 0.20 $\mu g{\cdot}g^{-1}$ recommended for fish used for subsistence, while 36% of the lake trout had concentrations at or above the recommended guideline level of 0.50 $\mu g{\cdot}g^{-1}$ for commercial fish. The highest concentration measured (1.8 $\mu g{\cdot}g^{-1}$) was in an old male (> 30 years) and was almost four-fold higher than the subsistence recommended guideline.

Mean and length adjusted Hg concentrations in lake trout muscle and burbot liver from a selection of Yukon Lakes are shown in Table 2. Figure 2 shows the relationship between log [Hg] and length for lake trout (muscle) and burbot (liver). Kusawa Lake lake trout had the highest Hg concentrations followed by Lake Laberge and Quiet Lake. In burbot liver, the Lake Laberge fish had slightly higher

Figure 1. Muscle mercury concentrations in lake trout of varying lengths collected from Kusawa Lake in 1999*



* The blue line corresponds to the guideline level of 0.50 $\mu g{\cdot}g^{-1}$ recommended for commercial fisheries.

Table 1. Means (standard deviation) and summary of ANCOVA results used to assess the effects of year-to-year collections (temporal trends), length and length*year interactions (homogeneity of the slope between length and [Hg]) of Hg in Lake Laberge burbot liver and lake trout muscle[1]

	Mean (SD)			Length (Pr[2])	Length*yr (Pr)	R^2 (model)	Length adjusted mean		
Trout	**1993**	**1996**	**1998**				**1993**	**1996**	**1998**
N	2	14	7	—	—	—	12	14	7
Length	483 (111)	489 (95)	700 (125)	—	—	—	—	—	—
Hg	0.44 (0.13)	0.33 (0.10)	0.61 (0.24)	< 0.0001	0.8604	0.69	0.49a[3]	0.35b	0.38b
Burbot	**1993**	**1996**	**1999**				**1993**	**1996**	**1999**
N	—	15	11	—	—	—	—	15	11
Length	—	429 (64)	648 (73)	—	—	—	—	—	—
Hg	—	0.08 (0.03)	0.21 (0.13)	< 0.0001	0.8381	0.55	—	0.10a	0.12a

[1] All concentrations are in $\mu g{\cdot}g^{-1}$.

[2] Probability

[3] Data in the same row followed by a different letter differ significantly ($p < 0.05$).

Hg concentrations than did the fish from Kusawa, Fox and Quiet Lakes.

Lake Laberge sediment cores

In March 2000, three sediment cores were collected from the north (LAB-6), central (LAB-7) and southern (LAB-5) areas of Lake Laberge using a 10 cm diameter gravity corer (Table 3). Surface sediments were undisturbed and each core was sliced into thin layers at the site of collection and sent to the Freshwater Institute (Winnipeg) for dating and chemical analyses. ^{210}Pb, ^{137}Cs and Hg analysis has been described previously by Lockhart et al. (2000).

^{210}Pb and ^{137}Cs profiles for each of the three cores are shown in Figure 3. The quality of dating was excellent as judged by the exponential declines with depth in excess ^{210}Pb. ^{137}Cs peaks placed in the mid-1960s, the time of maximum bomb fallout, in all three cores. Sedimentation rates and methods used to calculate them are listed in Table 3. The highest corrected sedimentation rate occurs in southern end of the lake, closer to the mouth of the

Table 2. Means (standard deviation) and summary of ANCOVA results used to assess the effects of location, length and length*location interactions (homogeneity of the slope between length and [Hg]) of Hg in Laberge, Kusawa, Fox and Quiet Lakes lake trout muscle and burbot liver samples[1]

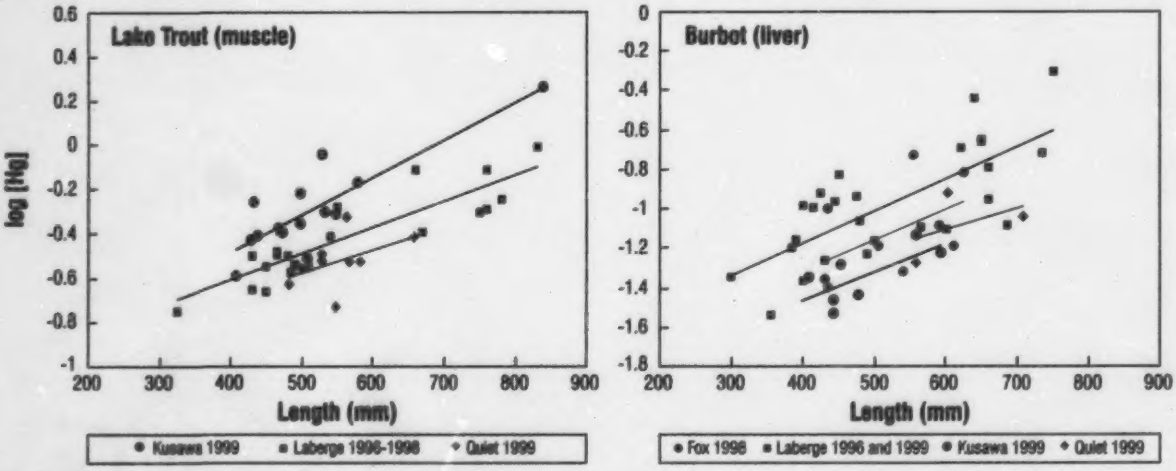
					Pr[2]	length*loc (Pr)	R^2 (model)	Length adjusted mean			
Trout	**Kusawa**	**Laberge**	**Fox**	**Quiet**				**Kusawa**	**Laberge**	**Fox**	**Quiet**
Year	1999	1996 & 1998	—	1999				1999	1996 & 1998	—	1999
N	14	21	—	9	—	—	—	14	21	—	9
Length	515 (106)	560 (145)	—	553 (52)	—	—	—	—	—	—	—
Hg	0.57 (0.39)	0.42 (0.21)	—	0.30 (0.08)	<0.0001	0.2614	0.74	0.55a[3]	0.36b	—	0.29c
Burbot	**Kusawa**	**Laberge**	**Fox**	**Quiet**				**Kusawa**	**Laberge**	**Fox**	**Quiet**
Year	1999	1996 & 1998	1998	1999				1999	1996 & 1998	1998	1999
N	7	26	9	3	—	—	—	7	26	9	3
Length	484 (68)	521 (129)	525 (78)	625 (77)	—	—	—	—	—	—	—
Hg	0.05 (0.02)	0.13 (0.11)	0.09 (0.05)	0.09 (0.03)	<0.0001	0.9898	0.60	0.05a	0.11b	0.08a	0.06a

[1] All concentrations are in $\mu g \cdot g^{-1}$.

[2] Probability

[3] Data in the same row followed by a different letter differ significantly ($p < 0.05$).

Figure 2. Relationship between log [Hg] and length for lake trout (muscle) and burbot (liver) from a selection of Yukon Lakes



Yukon River, and decreases northward along the lake. The focussing factor for each site was estimated by dividing the flux of ^{210}Pb to the sediment by the flux to the nearest soil sample.

The down-core profiles in concentration of Hg are shown in Figure 4. The flux of Hg can be calculated from the product of the concentration and the focus corrected sedimentation rate (Table 4). The concentrations can be taken for each slice or from any arbitrary group of them. Using the same procedure of Lockhart et al. (1998) the average concentrations for the slices deposited since the late 1940s to the early 1950s, for each core, were multiplied by the corresponding focus corrected sedimentation rates. The average Hg flux, over the period from ~1950-1999, ranged from 34.4 $\mu g \cdot m^{-2} \cdot y^{-1}$ in LAB-6 to 46.0 $\mu g \cdot m^{-2} \cdot y^{-1}$ in

Table 3. Core locations (within Lake Laberge) and data to calculate sedimentation rates and focussing factors

Core	Date collected	Site	Core length (cm)	Number of slices	Model	^{210}Pb flux ($Bq \cdot m^{-2} \cdot y^{-1}$)	Sedimentation rate ($g \cdot m^{-2} \cdot y^{-1}$)	Focus factor[1]	Corrected sedimentation rate ($g \cdot m^{-2} \cdot y^{-1}$)
LAB-5	13-Mar-00[2]	61 03.507 N; 135 06.526 W	32	40	CRS[3]	91	899	1.1	817
LAB-6	14-Mar-00[2]	61 16.104 N; 135 11.005 W	36	40	CRS	99	694	1.2	578
LAB-7	15-Mar-00[2]	61 10.185 N; 135 14.552 W	37	42	CRS	133	1140	1.7	671
KB-3	Mar-92[4]	61 12 N; 135 11 W	19	26	Linear	114	999	1.4	714

[1] Calculated using the ^{210}Pb flux in the lake sediment and the expected ^{210}Pb flux from soil data: 80 $Bq \cdot m^{-2} \cdot y^{-1}$

[2] Source: This study

[3] Constant Rate of Supply (Source: Oldfield and Appleby 1984)

[4] Source: Lockhart et al. 1998

Figure 3. Down-core profiles of ^{210}Pb and ^{137}Cs for three cores collected in Lake Laberge in March 2000

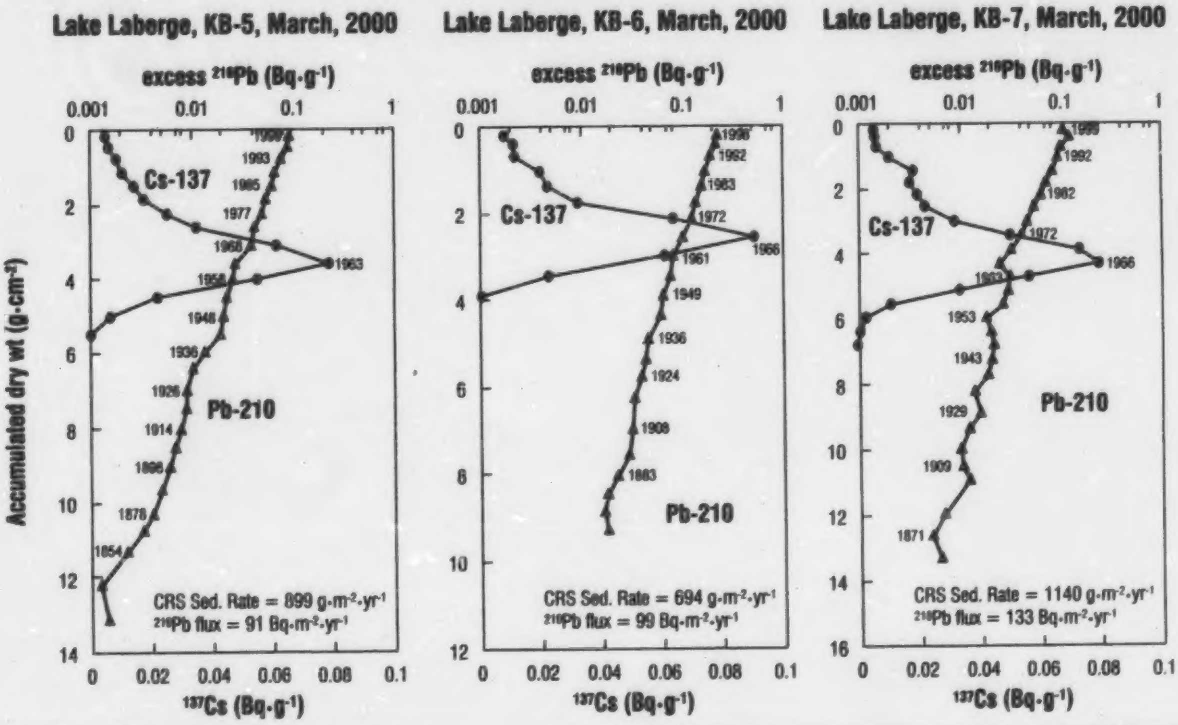
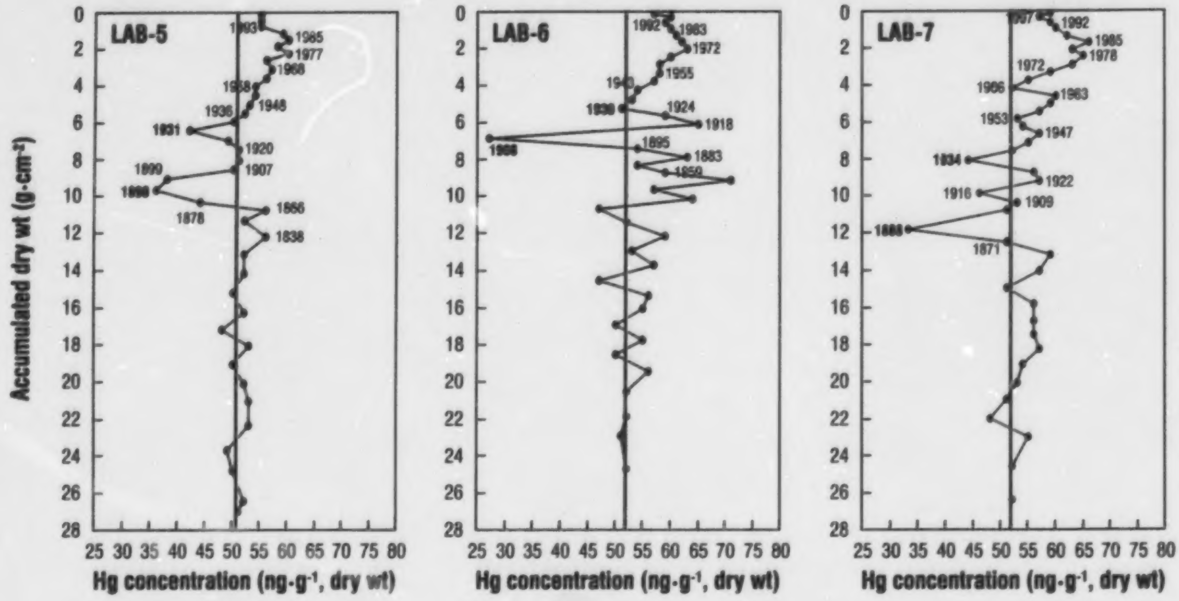


Figure 4. Down-core profiles of mercury concentrations in sediments from three selected locations in Lake Laberge*



* Vertical lines correspond to mean historical mercury concentration (five deepest slices).

LAB-5. The historical fluxes calculated from the deepest sections of the cores are taken to be the natural inputs resulting from all processes at the time the deep sections were deposited. Historical fluxes ranged from 30.4 $\mu g{\cdot}m^{-2}{\cdot}y^{-1}$ in LAB-6 to 41.7 $\mu g{\cdot}m^{-2}{\cdot}y^{-1}$ in LAB-5. In both recent and historical times, the influence of the Yukon River as a source of Hg to the lake sediments decreases in a northerly direction along the lake. The anthropogenic input of Hg to the lake sediments, calculated as recent minus historical fluxes, averaged 4.3 $\mu g{\cdot}m^{-2}{\cdot}y^{-1}$.

Results for a core collected from Lake Laberge in 1992 (Lockhart et al. 1998) have also been included in Tables 3 and 4 (sites KB-3 and LAB-7 are similar). Mean Hg concentrations in the sediment and the calculated fluxes, from both the recent and historical parts of KB-3, are approximately two-fold lower than is reported for the cores collected in the current study. This discrepancy is currently being looked into; despite this difference, the calculated anthropogenic fluxes are quite similar.

In the recent part of the cores (~1950-1999), Hg concentrations peak in LAB-5 and LAB-7 in the late 1970s

Table 4. Estimates of fluxes of mercury to the upper parts of the Lake Laberge cores since the 1950s (recent flux) as compared with fluxes to the five deepest slices in the same cores (historical flux)[1]

		Upper part of cores (recent)			Deepest part of core (historical)			Recent-Historical
Core	Date	Time period	Mean Hg (ng·g⁻¹ dry wt)	Hg Flux (µg·m⁻²·y⁻¹)	Time period	Mean Hg (ng·g⁻¹ dry wt)	Hg Flux (µg·m⁻²·y⁻¹)	Excess Flux (µg·m⁻²·y⁻¹)
LAB-5	13-Mar-2000[2]	1948-2000, slices 1-13	56.3	46.0	Slices 36-40	51.0	41.7	4.3
LAB-6	14-Mar-2000[2]	1950-2000, slices 1-11	59.5	34.4	Slices 36-40	52.6	30.4	4.0
LAB-7	15-Mar-2000[2]	1949-2000, slices 1-15	59.0	39.5	Slices 38-42	51.8	34.6	4.7
KB-3	Mar-1992[3]	1951-1992, slices 1-12	25.8	18.4	Slices 22-26	22.4	16.0	3.6

[1] The anthropogenic flux is taken as the difference between the recent and historical fluxes.

[2] Source: This study

[3] Source: Lockhart et al. 1998

Table 5. Estimates of fluxes of mercury to the upper parts of the Lake Laberge cores (surface and maximum) as compared with fluxes to the five deepest slices in the same cores (historical flux)

		Surface			Maximum			
Core	Date	Hg ($ng \cdot g^{-1}$ dry wt)	Hg Flux ($\mu g \cdot m^{-2} \cdot y^{-1}$)	Excess flux ($\mu g \cdot m^{-2} \cdot y^{-1}$)	Time periods	Hg ($ng \cdot g^{-1}$ dry wt)	Hg Flux ($\mu g \cdot m^{-2} \cdot y^{-1}$)	Excess flux ($\mu g \cdot m^{-2} \cdot y^{-1}$)
LAB-5	13-Mar-00[1]	55.0	45.0	3.3	1985, slice 7	60.0	49.0	7.3
LAB-6	14-Mar-00[1]	57.0	33.0	2.6	1972, slice 7	63.0	36.4	9.7
LAB-7	15-Mar-00[1]	59.0	39.6	5.0	1985, slice 6	66.0	44.3	6.0

[1] Source: This study

to the mid-1980s and slightly earlier in LAB-6, and then gradually decrease toward the surface. Excess of maximum and surface flux over the historical flux has been calculated in Table 5.

An interesting aspect observed in all three cores is the measured drop in Hg concentrations in the late 1880s, early 1900s and again in the early 1930s. These events may be attributed to a number of activities which occurred on the Yukon River system, starting in the late 1890s with the practice of the dredging of the Yukon River at the mouth of Lake Laberge to the building of the Marsh Lake Dam in 1924. The fact that each of the three cores records the same historical declines in Hg deposition to the lake sediment, whatever the causes may be, is good evidence that the fidelity of the cores are not substantially affected by processes such as biomixing and Hg remobilization.

Conclusions

The current work on Lake Laberge results from the unusually high contaminants levels that were found in lake trout (muscle) and burbot (liver) in 1991 and the recently observed declines. It is suggested that heavy fishing pressure in the past altered the foodweb structure in Lake Laberge: the abundance of lake trout declined while species such as burbot and sucker increased in abundance, compared to other regional lakes. Recent data indicates that in 1999 lake trout were twice as abundant as in 1991, presumably because of the closure of the fishery. Our aim is to exploit this "natural" experiment to better understand the processes controlling contaminant concentrations in northern fish populations. This improved understanding will assist with interpreting the inter-annual variability as well as inter-lake variability in fish concentrations that increases the uncertainty surrounding the interpretation of temporal and geographic trends.

Expected Project Completion Date

Temporal trend studies are long-term propositions and thus annual sampling is projected until at least 2005.

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Contaminants in Arctic Seaducks

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Abstract

We examined mercury, selenium and cadmium concentrations and immune function, stress response, body condition, vitamin A and glycogen levels in 21 common eiders, a seaduck species whose populations have been declining dramatically in the Arctic in recent years. The study was conducted at East Bay Migratory Bird Sanctuary on Southampton Island, Nunavut, in late June and July 2000. Multiple regression (forward selection method) revealed the following significant relationships ($p < 0.05$): body mass, heart mass and abdominal fat mass were inversely related, and hepatic retinol and retinyl palmitate were positively related to hepatic mercury concentrations; body and kidney masses were negatively related to renal cadmium concentrations. There were no significant ($p > 0.05$) relationships between trace metal concentrations and immune function, stress response or liver glycogen levels.

Key Project Messages

1. There is growing evidence that populations of seaducks are declining in the Arctic. It has been suggested that contaminants, especially metals, may be one of the environmental stressors contributing to these declines.
2. In some communities in the Canadian Arctic, seaducks are an important traditional food. Declining populations could impact the harvest of these birds. In addition, high contaminant levels could detract from the perceived quality of seaducks as traditional foods.
3. Because of our concerns about sublethal effects of contaminants on seaducks, we investigated relationships between metal concentrations and certain measures of health and fitness in a representative species of seaduck, the common eider.
4. The study was done at the East Bay Migratory Bird Sanctuary on Southampton Island, Nunavut.
5. Overall, we found no consistent evidence that tissue metal concentrations in these birds were adversely affecting their health and fitness. It is unlikely that metals are contributing to population declines by weakening the resistance of these birds to other types of environmental stress.
6. A human health assessment concerning the levels of trace metals in livers and kidneys of seaducks in the Arctic was recently completed by Health Canada. The results of that assessment were sent to the Nunavut and Northwest Territories Contaminants Committees for dissemination to the communities.

Objective

- To determine whether trace element levels in seaducks (common eiders) are related to selected measures of their health and fitness, including body condition, immune function, stress hormone response, and retinol and glycogen concentrations.

Introduction

Northern governments and communities are interested in obtaining information to ensure a sustainable harvest of seaduck species used for traditional/country food. In the Inuvialuit Settlement Region, hunters harvest 2000 to 5000 eiders each year (Fabijan et al. 1997). It has been estimated that approximately 14,000 eiders were harvested each year in Nunavut in the early 1980s (Turner et al. 1996). The Nunavut Wildlife Management Board has ranked seaducks (specifically eiders) among their priority species of concern (Nunavut Wildlife Management Board Research Priorities, Arviat meeting, Jan. 19 to 23, 1998), presumably because of population declines. Populations of several species of North American seaducks (Mergini) have declined precipitously in recent years. Contaminants are believed to be one of several risk factors that may be contributing to these declines (Canadian Wildlife Service et al. 1997). Trace elements, in particular cadmium (Cd), selenium (Se) and, to a lesser extent, mercury (Hg) have been found at elevated concentrations in North American seaducks (Henny et al. 1991, 1995, Hoffman et al. 1998, Trust et al. 2000, Wayland et al. 1999a, 1999b).

There is little useful information concerning the possible effects of toxic trace elements on seaducks. Most information comes from laboratory-based, captive-feeding experiments wherein surrogate species such as the mallard (*Anas platyrhynchos*) were exposed to relatively high levels of single trace elements (DiGiulio and Scanlon 1985, Heinz et al. 1989, Bennett et al. 2000). However, there have been few attempts to corroborate the findings of such studies by examining wild seaducks living under natural conditions. Such studies are required because experimental, captive-feeding trials typically are not representative of the full range of concentrations of the many trace metals to which seaducks are simultaneously exposed in the wild. Nor do they consider the possible interactive effects of trace metal exposure and natural environmental stressors of the type that wild animals normally encounter.

Biomarkers have been used routinely in recent years to assess the health of wildlife in relation to their exposure to contaminants (Peakall 1992). For example, changes in the immune system, which can affect susceptibility to disease, may provide sensitive, early warning signals of the toxic effects of contaminants, including metals (Lawrence 1985, Weeks et al. 1992). The response to acute stress, as evaluated by measurements of corticosteroids, is another biomarker that may be affected by some trace metals (Hontela 1997). Corticosteroids regulate processes related to energy metabolism, salt gland function and immune function (Hontela 1997) and, therefore, are important in the maintenance of homeostasis in animals. Glycogen is an important form of stored energy reserves, especially in fasting animals. Common eider females, the subject of this study, fast during incubation. Therefore their glycogen reserves may be an important source of energy during incubation, the period during which this study was conducted. Furthermore, glycogen metabolism is under the control of corticosteroid hormones (Hontela 1997). Thus, any effect of trace metals on corticosteroids could affect glycogen stores.

Another biomarker that has been related to trace element exposure is body condition (Debacker et al. 2000, Yamamoto and Santolo 2000), which is an important determinant of fitness and survival in ducks (Milne 1976, Bergan and Smith 1993, Blums et al. 1997). Finally, vitamin A is another biomarker that can be influenced by contaminants, especially those that are lipophilic (Rolland 2000). Also, there is some evidence that metals, especially Cd, can affect vitamin A storage and metabolism (Sugawara and Sugawara 1978, Massanyi et al. 1999).

The northern common eider (*Somateria mollissima borealis*) is a seaduck that breeds principally in Arctic and sub-Arctic coastal areas of Canada. Like other species of seaducks in North America, its population is believed to have declined in recent years (Canadian Wildlife Service et al. 1997). Concentrations of most trace metals in the common eider are fairly similar to those in several other species of seaducks in North America (Henny et al. 1991, 1995, Hoffman et al. 1998, Trust et al. 2000, Wayland et al. 1999a, 1999b, 2000). Unlike most other species of seaducks, it nests in colonies, making it relatively easy to catch, and obtain blood and other types of samples from large numbers of birds in the field. For these reasons, it is likely a good sentinel species for evaluating the effects of trace metals on seaducks.

In this study, we examined selected measures of health and fitness in common eider ducks breeding at the East Bay Migratory Bird Sanctuary on Southampton Island, Nunavut. In particular, we determined whether relationships exist between tissue concentrations of Hg, Se and Cd and body condition, immune function, stress response, retinol levels and glycogen levels.

Activities in 2000-2001

The study was carried out on June 28 to July 27, 2000, at the East Bay Migratory Bird Sanctuary on Southampton Island, Nunavut (64°04′ N, 81°40′ W). Twenty-one female common eider ducks were sampled during the incubation period. Several measures of body condition were evaluated along with trace element concentrations, stress response, immune function, retinol concentrations and liver glycogen content.

Immune function

Immune function was assessed by using two assays, (1) the antibody response to an injection of sheep red blood cells (SRBC) and (2) the skin swelling response to an injection of phytohemagglutinen-P (PHA-P). The former promotes a humoral immune response while the latter elicits a simple, rapid cell-mediated immune response.

Ten common eiders were used for the SRBC experiment. Two mL of a 20% solution of SRBC in sterile phosphate buffered saline (PBS) were injected intraperitoneally following initial capture. Antibody levels peak about 7 to 9 days after SRBC injection; therefore, the eiders were released back to the wild for a period of 7 days. Birds were recaptured 7 days later and held in captivity in a flight pen for 1 day at which time a blood sample was drawn from the brachial vein. Within minutes, samples were centrifuged and the plasma was frozen in liquid nitrogen. The plasma samples were sent to the University of Saskatchewan where hemagglutination titers were performed according to standard techniques (Fairbrother and Fowles 1990) to assay the total antibody response to SRBC injection.

Cell-mediated immune response was determined in 21 eiders. Following capture (the second capture for eiders that were assayed for hemagglutination titers to SRBC; the first capture for the remaining 11 eiders), a small section of both wing webs was plucked and the thickness was measured with a pressure-sensitive micrometer. Then 0.1 mL of PHA-P in PBS (1.0 mg·mL^{-1}) was injected intradermally into the right wing and 0.1 mL PBS alone was injected into the left wing web. The injections were made at the exact site where wing web thickness was measured. Following PHA-P injection, the birds were placed in a large (2.4 X 7.4 X 1.2 m) flight pen. While in the pen, the ducks were supplied with fresh water ad libitum. Following a 24-hour period, the thickness of both wing webs was remeasured. The cell-mediated immune response to PHA-P was calculated using two different methods: (1) CMI1 = the difference in right wing web thickness (postPHA to prePHA) minus the difference in left wing web thickness (postPBS to prePBS) and (2) CMI2 = the difference in right wing web thickness (postPHA to prePHA) (Smits et al. 1999).

Stress response

Stress response was assessed in all 21 eiders. Following capture (the second capture for SRBC eiders; the first capture for the remaining 11 eiders), two blood samples were drawn from the brachial vein, one at approximately 7 minutes following capture and another at approximately 40 minutes following capture. Each bird was placed in a canvas sack in between blood samples. The time of capture and of completion of each blood sample was recorded. All blood samples were centrifuged and the plasma was frozen within 12 hours. Corticosterone levels were determined in the thawed plasma samples by radioimmunoassay at the University of Saskatchewan. Stress response was defined as the difference in residual corticosterone concentration between the first and second samples. Residuals were derived from the regression of corticosterone concentration on time elapsed since capture.

Body condition

Body mass of all eiders was recorded before and after the 24-hour captive period. Following the captive period and after the blood collections were completed, the birds were sacrificed via halothane inhalation. Bill length, head length, nostril length, culmen length, tarsal length, wing length and keel length were measured. The liver, kidneys, spleen, heart, abdominal fat and left pectoral muscle were removed and weighed. Liver and kidneys were placed, separately, in acid-washed glassware and frozen for subsequent analyses.

Retinol and glycogen

A portion of the plasma from samples for hemagglutination titers (see above) were used for determination of plasma retinol. A thin slice of liver, removed within minutes of sacrificing each bird, was frozen in liquid nitrogen. These samples were sent to the University of Saskatchewan for further analyses. Liver samples were assayed for retinol, retinyl palmitate and glycogen, while plasma samples were assayed for retinol. Retinol/retinyl palmitate was extracted from samples using standard methods (Bishop et al. 1999) and extracts were analyzed by nonaqueous reverse-phase high-performance liquid chromatography. Glucose was extracted from liver samples using methods described in Keppler and Decker (1974). Extracts of free and total glucose were analyzed using the calorimetric glucose oxidase method (Raabo and Terkildsen 1960). Glycogen concentrations were determined by subtracting free glucose from total glucose.

Trace elements

Frozen liver and kidney samples were sent to Environment Canada's National Wildlife Research Centre in Ottawa. Total hepatic Hg was determined by cold vapour atomic absorption spectrometry, hepatic Se was determined by graphite furnace atomic absorption spectrometry and renal Cd was determined by flame atomic absorption spectrometry.

Results

Trace elements

Geometric mean levels of renal Cd, hepatic total Hg and hepatic Se were, respectively, 164.58, 3.32 and 16.15 $mg \cdot g^{-1}$ dry wt (Table 1).

Body condition

Multiple regression analyses (forward selection method) (Table 2) revealed significant inverse relationships between trace element levels and the following indices of body condition: a) final body mass vs. Hg ($p = 0.01$) (Figure 1) b) heart mass vs. Hg ($p = 0.01$) (Figure 1), c) abdominal fat mass vs. Hg ($p = 0.004$) (Figure 1), d) initial body mass vs. Cd ($p = 0.02$) (Figure 2), and e) kidney mass vs. Cd ($p = 0.02$) after adjusting for Se effects. Trace elements had no significant effect on liver mass or spleen mass (Table 2).

Stress response

There was a significant relationship between corticosterone level and time (minutes elapsed since capture) ($p < 0.0001$). Corticosterone levels increased from the first to the second blood sample (Figure 3). Thus, the change in corticosterone concentrations between the first and second sample provided a good indication of the stress-induced response to capture.

Table 1. Means, 95% confidence limits and ranges of hepatic selenium, total hepatic mercury and renal cadmium concentrations ($\mu g \cdot g^{-1}$) in 21 female common eiders

Trace Element	Mean	95% CL	Range
Se	16.15	12.82 - 20.35	6.51 - 47.45
Hg	3.32	2.63 - 4.19	1.51 - 9.81
Cd	164.58	138.03 - 196.25	74.11 - 389.09

Table 2. Results of forward multiple regressions between trace element concentrations and response variables

Variable	Model step	Trace element	Slope	Partial r^2	Probability > F
Liver mass	1	Hg	-0.10	0.14	0.09
Kidney mass	1	Se	0.12	0.15	0.08
	2	Cd	-0.19	0.21	0.02[1]
Heart mass	1	Hg	-0.17	0.33	0.01[1]
Spleen mass	—	—	—	—	0.48
Abdominal fat mass	1	Hg	-1.28	0.36	0.004[1]
Initial body mass	1	Cd	-0.14	0.26	0.02[1]
	2	Hg	-0.07	0.11	0.1
	3	Se	0.07	0.11	0.08
Final body mass	1	Hg	-0.12	0.28	0.01[1]
	2	Cd	-0.11	0.14	0.06
Stress response	—	—	—	—	0.18
SRBC total antibody response	—	—	—	—	0.15
CMI response (1)	—	—	—	—	0.27
CMI response (2)	—	—	—	—	0.19
Serum retinol	—	—	—	—	0.39
Liver retinol	1	Hg	0.82	0.32	0.01[1]
Liver retinyl palmitate	1	Hg	291.76	0.20	0.04[1]
Liver glycogen	—	—	—	—	> 0.50

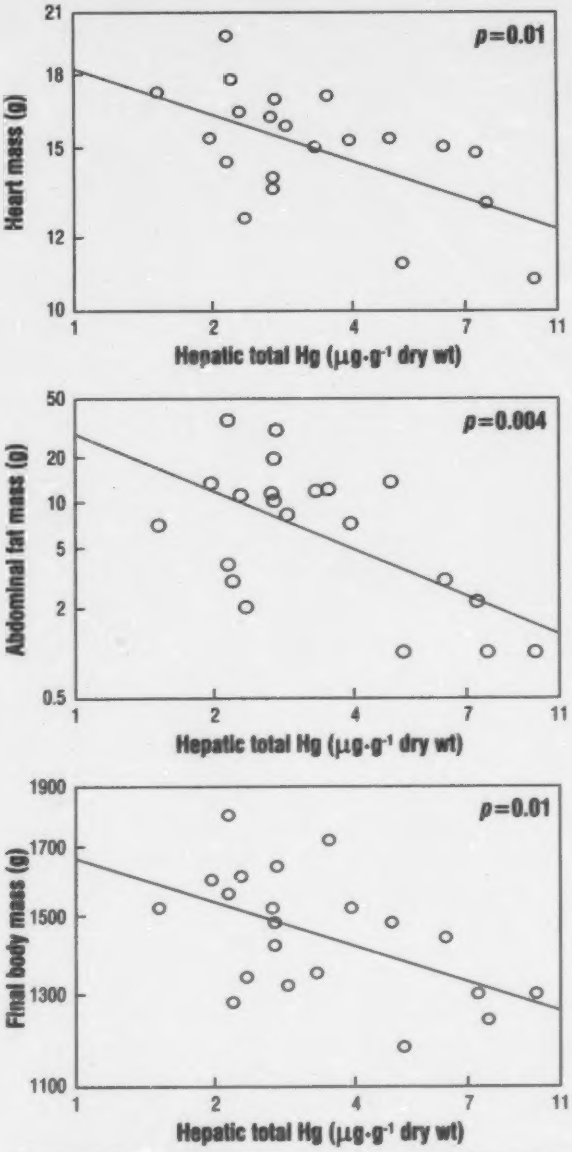
[1] Significant results ($p < 0.05$)

Stress response was not significantly affected by trace element levels ($p = 0.18$) (Table 2).

Immune function

Total antibody response to SRBC was not significantly affected by trace element levels ($p = 0.15$) (Table 2). Neither method of calculating cell-mediated immune response to PHA-P resulted in a significant relationship with trace element concentrations ($p = 0.19$) (Table 2).

Figure 1. Relationships between body condition measures and total hepatic mercury (μg·g^{-1} dry wt) in female common eiders



Retinol

Mercury had significant effects on both liver retinol ($p = 0.01$) and liver retinyl palmitate ($p = 0.04$) (Figure 4). Serum retinol was not affected by trace elements ($p = 0.39$) (Table 2).

Glycogen

Trace elements concentrations were not significantly related to liver glycogen content ($p > 0.50$) (Table 2).

Discussion

Trace elements

Concentrations of Hg, Se and Cd were similar to, or slightly higher than, those reported in eider ducks from Europe (Karlog et al. 1983, Norheim 1987, Nielsen and Dietz 1989, Hollmen et al. 1998, Franson et al. 2000) and the Canadian Arctic in earlier years (Wayland et al. 1999a, Wayland et al. 2000). Selenium concentrations were lower than those found in eiders in Alaska (Trust et al. 2000). Trace element concentrations were especially similar to concentrations in eiders at East Bay Migratory Bird Sanctuary in 1998, a year in which incubating eiders were collected for analysis, similar to the approach used in this study (Wayland et al. 1999b). The concentrations of Hg and Cd in incubating eiders in 1998 and 2000 were higher than in pre-nesting eiders in 1997 and 1999, probably as a result of tissue mass loss associated with fasting in incubating birds. Eiders lose about 30% of their body weight during incubation (Parker and Holm 1990). Because metals such as Cd and Hg are effectively bound to metallothionein in liver and kidney, they are relatively immobile with long tissue turnover times (Scheuhammer 1987). Thus, as tissue mass declined in incubating

Figure 2. Relationships between initial body mass and renal cadmium (μg·g^{-1} dry wt) in female common eiders

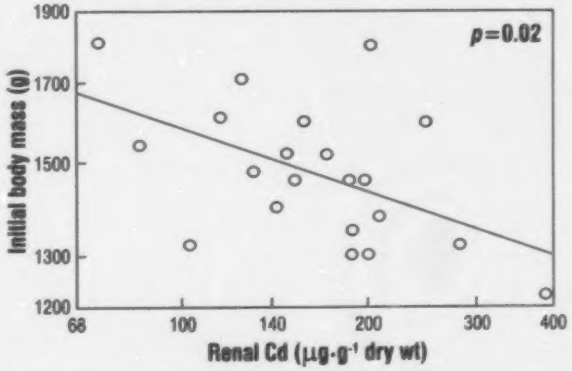


Figure 3. Relationships between plasma corticosterone (ng·mL⁻¹) and time sice capture in female common eiders

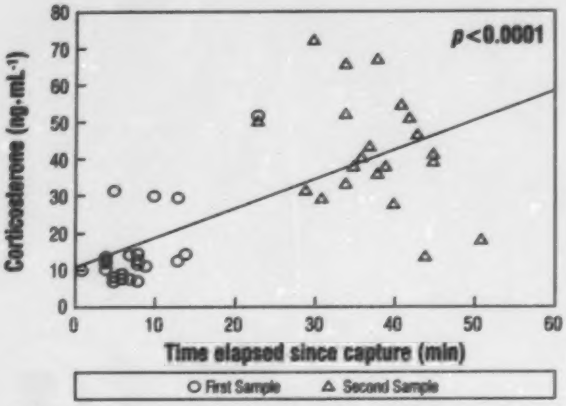
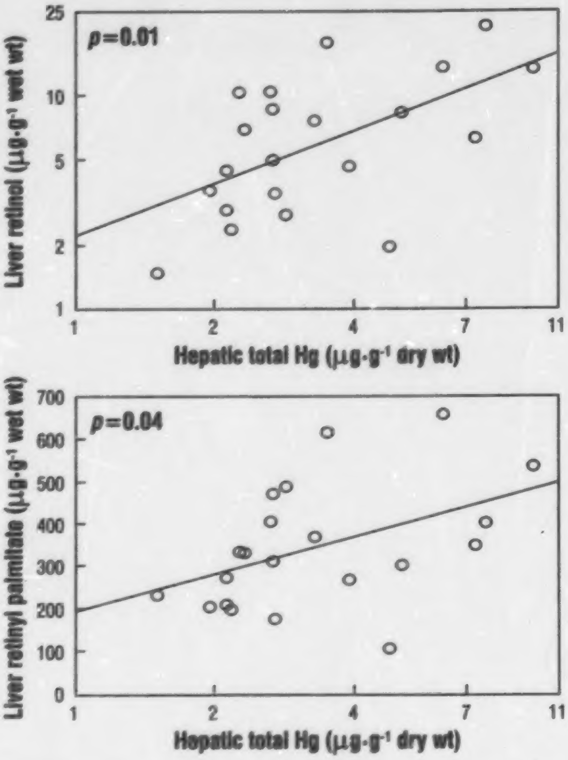


Figure 4. Relationships between retinol and retinyl palmitate (µg·g⁻¹ wet wt) and hepatic total mercury (µg·g⁻¹ dry wt) in female common eiders



eiders, these metals likely became increasingly concentrated in the remaining tissue.

Body condition

As in earlier years, we found that Hg and Cd concentrations were negatively related to various body condition indices, most notably body mass and abdominal fat mass. Studies have shown (Milne 1976, Bergan and Smith 1993, Blums et al. 1997) and it is now widely accepted that body mass and fat stores are important determinants of fitness and survival in ducks. Because of their importance to fitness and survival, Henny et al. (1991) postulated that the negative relationship between Cd concentration and body mass in seaducks on the Pacific coast may be a cause for concern. Implicit in their concern was that there may have been a cause-effect relationship between Cd and body mass in those birds. In the intervening years, other field studies also have reported negative relationships between metal concentrations in various tissues of seaducks and indices of their body condition (Ohlendorf et al. 1991, Hoffman et al. 1998, Franson et al. 2000). However, these findings have generally not been supported by experimental studies, wherein captive birds have been fed a range of concentrations of Hg or Cd. For example, in a multi-generation study, mallards that were fed 0.5 µg·g⁻¹ methylmercury (MeHg) in their diets accumulated approximately 1.5 µg·g⁻¹ (wet wt) Hg in their livers. Body weights of adults that were fed the Hg-containing diet did not differ from those receiving a control diet (Heinz 1979). Similarly, body weights of mallards with hepatic Hg concentrations of 22 µg·g⁻¹ (wet wt) after being fed 10 µg·g⁻¹ dietary MeHg about 2.5 months were not different from those of mallards that received a control diet and had hepatic Hg concentrations below 1 µg·g⁻¹ (Heinz and Hoffman 1998). Body weights of ducks fed Cd at 2 µg·g⁻¹ to 200 µg·g⁻¹ (White and Finley 1978; Di Giulio and Scanlon 1985; Bennett et al. 2000) did not differ from those of control ducks. Dietary Cd at 300 µg·g⁻¹ was associated with body mass loss and other toxic effects (Bennett et al. 2000). However, it is extremely unlikely that the food of wild seaducks would have such high concentrations of Cd (Lande 1977, Dietz et al. 1996).

The lack of agreement between the results of experimental feeding studies and field studies may indicate that Cd and Hg can affect wild birds through indirect mechanisms that are not operational in captive feeding studies. A more probable explanation is that, in the wild, normal seasonal changes in body and organ mass directly affect concentrations of relatively immobile trace elements such as Cd and Hg. For example, during periods of fasting with consequent loss of body and organ mass, Cd and Hg may become increasingly concentrated in kidney and liver. In contrast, when birds are gaining weight, as occurs during the pre-laying period in eiders, Cd and Hg may become increasingly diluted in the rapidly-expanding tissue pool. Thus, concentrations of Hg and Cd were lower in pre-nesting eiders sampled in 1999 compared to incubating, fasting eiders sampled in 2000. Therefore, it is possible that the inverse relationships between body/organ mass and Hg/Cd concentrations in this study simply reflect the relative degree to which individual birds are gaining or losing weight at the time they are sampled, rather than an effect of the metals on metabolic pathways affecting body and organ mass.

Stress response

In this study, the stress response was not related to trace element concentrations. This contrasts with our earlier finding that Cd concentrations were positively correlated with the stress response of incubating eiders sampled in 1998 (Wayland et al. 1999b) and that Se concentrations were negatively related to the stress response in females in 1999 (Wayland et al. unpublished data). It also is inconsistent with observations that Cd increased corticosterone secretion in food-restricted ducks (Di Giulio and Scanlon 1985) and that Se can decrease corticosterone synthesis in seal adrenals in vitro (Freeman and Sangalang 1977). Yet, the absence of a relationship between the stress response and trace metal concentrations is consistent with results from pre-nesting eiders that we sampled in 1999, when neither Cd nor Hg levels were related to the stress response. While it has been demonstrated experimentally that trace metals can alter glucocorticoid levels in fish (Hontela 1997) and seal adrenal cells (Freeman and Sangalang 1977), the absence of consistent, repeatable relationships reported in this study and in our 1999 study (Wayland et al. 2000), suggests that trace metal exposure in these eiders may have been lower than critical threshold levels of exposure required to produce effects on corticosteroids.

Immune function

Mercury and Cd can be immunotoxic, while Se can enhance or disrupt the immune response depending on whether it is available at deficient, adequate or excessive levels in the diet (Descotes 1992, Reilly 1996, Pollard and Hultman 1997). We did not find relationships between immune function and Cd or Hg levels. This is consistent with results from birds that we sampled in 1999 (Wayland et al. unpublished data). Selenium also had no apparent effects on immune function in this study, in contrast to the positive relationship between Se and the PHA-P skin response in females sampled in 1999 (Wayland et al. unpublished data). We have found no evidence that Hg, Cd or Se exposure is impairing the immune response of common eiders.

Vitamin A

Hepatic Hg concentrations were positively related to liver retinol and retinyl palmitate but not to plasma retinol. This was unexpected. Very high dietary concentrations of Hg have been associated with decreased vitamin A stores (Abdelhamid 1988, Raszyk et al. 1992). However, the effects of environmentally-realistic levels of Hg are not known. Zinc is believed to be important in mobilizing vitamin A from liver to blood (Ette et al. 1979). If Hg can reduce zinc bioavailability for vitamin A metabolism through induction and binding to metallothionein, then it is conceivable that Hg could indirectly affect vitamin A metabolism through its interaction with zinc. We plan to review what is known on this topic in the coming months in order to better assess the plausibility of this finding.

Glycogen

When trace metals disrupt the hypothalamo-adrenal axis, liver glycogen levels are often secondarily affected (Hontela 1997). Therefore, to determine whether contaminant-induced changes in corticosteroid concentrations have a physiological consequence, it may be important to examine glycogen levels. In this study, liver glycogen was not related to trace metal concentrations. This was not surprising, since corticosterone concentrations were not affected by trace metal exposure in these eiders. Similar to the results of this study, liver glycogen levels in Cd-dosed ducks were similar to those in controls (Di Giulio and Scanlon 1985).

Conclusions

We found no consistent evidence over the 4 years of this study that the health and fitness of eiders ducks was related to trace metal concentrations in their tissues. Results for immune function and stress response that may have indicated an adverse effect of trace metal exposure were not consistent from one year to the next. The absence of consistency in such relationships severely weakens any conclusions that can be made about the relationship of trace metal exposure to health and fitness. We did find consistent relationships from one year to the next between trace metal concentrations and indices of body condition. While these findings were consistent with those found in other published studies of wild seaducks, they were not supported by captive-feeding studies, where birds were experimentally-dosed with varying concentrations of selected trace metals. It is probable that the inverse relationships between trace metal concentrations and body condition resulted from normal seasonal patterns of fluctuations in body mass in these ducks.

Expected Project Completion Date

March 2002

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Monitoring the Health of Arctic Peoples and Ecosystems and the Effectiveness of International Controls

Part C: Local Contaminants Concerns

Heavy Metal Analyses of Wild Edible Mushrooms in the North Great Slave Lake Region, Northwest Territories

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Abstract

The analysis of potential contaminants in wild edible mushrooms is a requisite for the safe consumption of fungi by people in the Northwest Territories. From 1997 to 1999, samples of fungi and soil were collected in popular harvest areas of the North Great Slave Lake region, Northwest Territories, including sites exposed to emissions and sites in assumed pristine areas. Laboratory analysis revealed a positive relationship between concentrations of heavy metals in fungi and in soil. Accumulation of heavy metals in mushrooms was species-specific. Because of the high concentrations of metals in edible mushrooms of the North Great Slave region relative to all known national and international standards, extreme caution is urged in the selection of harvest sites. At locations close to roads, communities or mines, mushrooms should not be harvested at all. Mushrooms from the family *Agaricaceae* should be avoided completely because of their high bioaccumulation properties for toxic metals. Further assessment and public reporting is recommended.

Key Project Message

- Avoid the consumption of mushrooms from contaminated sites and sites exposed to emissions.

Objectives

1. Determine levels of contaminants in local Northwest Territories (NWT) mushrooms.
2. Identify safe harvest areas and recommend the avoidance of potentially contaminated mushrooms.

Introduction

In the NWT, popular edible mushrooms have been growing in significant numbers in the most frequented local picking spots, including road sides, city parks, industrial sites and edges of tailings (Green 1989). European scientific literature has fully demonstrated, however, that edible mushrooms from such locations can be highly contaminated and may pose a health hazard for humans and wildlife. Findings have been sufficiently grave that scientists and European governments have cooperated to alert and educate the public about avoiding contaminated mushrooms (Barcan 1998, Falandysz and Chwir 1997, Garcfa et al. 1998, Kalac et al. 1996, Larsen et al. 1998, Minagawa et al. 1980, Slejkovec and Irgolic 1996).

Canada is one of the leading producers of wild mushrooms, valued at $1.3 billion annually on the world market (Mohammed 1999). In the NWT, wild gourmet mushrooms are a considerable renewable resource. Their harvest, and local and commercial use have been increasing. NWT-mushrooms have been sold to markets across North America and Europe (Obst and Brown 2000). The analysis of potential contaminants in mushrooms is a requisite for the safe use, export and marketing of NWT-mushrooms. Therefore, a laboratory analysis of local wild mushrooms was completed.

Activities in 2000-2001

From 1997 to 1999, samples of 15 species of popular local wild mushrooms and their associated soils were collected and analyzed for potential contaminants. Samples were collected at 40 random locations in an area of 50 km x 200 km centering around the city of Yellowknife. Sampling locations included popular picking areas, impacted sites exposed to emissions, and undisturbed and inaccessible sites up to 100 km away from pollution point sources.

These samples were analyzed by the Taiga Environmental Laboratory, Yellowknife, in 1999. All samples were screened for 27 elements and/or contaminants. Results were used to determine if contaminants in mushrooms were within tolerable levels for food according to Canadian and international standards, and if results are comparable with results of foreign studies.

Activities in 2000-2001, focussed on the completion of data entry and analysis, and report writing.

Results

Total arsenic levels in fungi ranged from 0.20 to 494.00 $mg \cdot kg^{-1}$ in dry weight (wt). The bioaccumulation ratios of arsenic from soil to fungi were highest in the family *Tricholomataceae* with factors ranging from 4 to 22.5 times the levels in soil. Arsenic speciation in two samples of fungi indicated that organic arsenic compounds represented more than 99.75 % of total arsenic. Total lead levels in fungi were high in all samples and ranged from 5.20 to 1010.00 $mg \cdot kg^{-1}$ dry wt. The bioaccumulation ratios of lead from soil to fungi were highest in the family *Boletaceae* (0.12 to 67 times), closely followed by *Morchellaceae* and *Agaricaceae*. The highest bio-accumulation of cadmium was observed in *Agaricaceae* (1.6 to 85.5 times), and for mercury in *Tricholomataceae* (19 to 170 times) and *Agaricaceae* (9.6 to 165 times).

The human intake of four heavy metals through local fungi was calculated for 175 recreational harvesters and 1175 residents in the Yellowknife area. The results were compared with Canadian, World Health Organization (WHO) and other international health standards including the provisional tolerable daily intake (PTDI) (World Health Organization 1976a, 1976b, 1977, 1981, 1989, 1992, 1993, 1995).

The calculated annual intake of organic arsenic for some harvesters was 1.1 to 1.8 times the total annual tolerable level of the WHO PTDI. The seasonal (60 days) daily intake of arsenic for all harvesters ranged from 0.001 to 11.4 times the WHO PTDI. The seasonal and annual tolerable intake of organic arsenic for most of 1275 people with a low consumption rate of fungi was well below the WHO PTDI, while the intake for some people was near the tolerable level. The seasonal consumption of 1 kg of fresh mushrooms exceeded the WHO PTDI for organic arsenic for several families of fungi and locations. For comparison, concentrations of total arsenic in all samples of local fungi were 0.04 to 99 times the Russian standard in food.

The calculated intake of lead through fungi for many harvesters was 1.5 to 6.7 times (annual) and 9 to 40.7 times (seasonal) the Canadian PTDI. The intake of lead for most residents was 0.2 to 0.4 times (annual) and 1.4 to 2.8 times (seasonal) the Canadian PTDI, including people with a low consumption of 1 kg of fresh fungi. The seasonal consumption of 1 kg of fresh mushrooms exceeded the Canadian PTDI for several families of fungi and locations. Levels of lead in all samples of local fungi exceeded the standards for Russia, Poland, Czech and Slovak republics, from 9 to 337 times.

The calculated intake of cadmium through fungi for some harvesters was 0.08 to 0.09 times (annual) and 0.49 to 0.52 times (seasonal) the Canadian PTDI. For the remaining consumer groups, the annual and seasonal intake of cadmium was insignificant. Elevated levels of cadmium in fungi ranged from 1.10 to 32.40 $mg \cdot kg^{-1}$ dry wt. Noteworthy high concentrations of cadmium were in *Agaricaceae* (8.20 to 17.10 $mg \cdot kg^{-1}$). Most local samples of fungi exceeded the Czech/Slovak standards from 1.2 to 34.2.

The calculated intake of mercury for some harvesters was 0.03 to 0.04 times (annual) and 0.16 to 0.26 times (seasonal) the Canadian PTDI. For other consumer groups, the annual and seasonal intake of mercury through fungi was insignificant. The consumption of 1 kg of fresh fungi with the highest concentration of mercury was 0.02 times (annual) and 0.15 times (seasonal) the Canadian PTDI. Mercury levels in nearly half of the local samples of fungi exceeded the Czech/Slovak standards from 1.1 to 9.8 times.

Discussion and Conclusions

Because of the extremely high concentration of metals in edible mushrooms of the North Great Slave region relative to all known national and international standards, we urge extreme caution in the selection of harvest sites, and we urge further assessment and public reporting. At locations close to roads, communities or mines, mushrooms should not be harvested at all. Mushrooms from the family *Agaricaceae* should be avoided completely because of their high bioaccumulation properties for toxic metals.

We recommend that responsible authorities advise the public not to harvest mushrooms from areas exposed to emissions and from contaminated sites such as locations near mine sites, tailings, crushed waste rock fill, landfills, road sides, parking lots, disturbed areas, communities and cities. Based on the results of our sampling regime, we recommend avoiding areas within at least 30 km of Yellowknife, and within 2 km from heavily used roads. Furthermore, we recommend additional sampling of soil and fungi including forest fire burn sites, and in control sites far away from infrastructures and pollution sources.

Expected Project Completion Date

A final report was released in mid-June 2001.

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Yukon Local Contaminants Concerns

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Yukon Contaminants Committee

Abstract

The Yukon Contaminants Committee (YCC) provides direction to the Local Contaminants Concerns (LCC) program. LCC is intended to address concerns raised by Yukon communities and individuals related to suspected local sources of contamination. In addition to planned projects, there are a number of unplanned or "walk-in" issues that arise every year. These issues arise over the course of an operational year and are typically initiated through a phone call or visit by persons with concerns associated with a specific contaminant or location. In some years the volume of these "walk-in" projects can represent a majority of the projects under LCC. 2000-2001 was an atypical year in that most of the program focus was on one planned project. Research conducted on Lake Laberge in 1990-1991 led to the implementation of a consumption advisory for lake trout flesh and burbot livers, which is still in place. LCC decided to revisit the Lake Laberge issue after a catch per unit effort study by the territorial Fisheries Division, in 1999, indicated that the population of lake trout had increased significantly since the previous study in 1991. A research project was initiated with the Department of Fisheries and Oceans, Central and Arctic Region (Winnipeg), which had been involved in previous studies on the lake. The joint program is collecting fish for analysis to determine if contaminant levels in lake trout and burbot have changed in relation to population dynamics. This initial investigation will form the basis for a graduate thesis study to take place in 2001-2002 and 2002-2003.

Other work conducted under LCC was the analysis of lake trout from Mandana Lake provided by the Carmacks Little Salmon First Nation, as part of their implementation of self-government, through the land claims process.

Key Project Message

- The Yukon Local Contaminants Concerns (LCC) program provides a timely response to local issues, provides a format to deal with unplanned, or "walk-in" concerns, identifies issues that may become major investigations under the Northern Contaminants Program or clean up projects under the Waste Management Program, and feeds into the local regulatory process for dealing with contaminated sites.

Objectives

1. Address local concerns regarding contaminants in a timely manner.
2. Provide a cost-effective evaluation process for local contaminants concerns.

Introduction

The Yukon LCC program provides a format to respond to local concerns on point source contaminants. The process includes planned projects and those that "walk-in" to the Regional office. In some years, the "walk-in" projects compose a majority of the program.

Work under the LCC varies yearly, but usually focusses on a point source of contamination and its effect upon a food source of some kind. Often the projects undertaken are for the "peace of mind" of a given community. Where a point source is identified, the LCC determines who is the appropriate regulatory agency to deal with the site and turns over all available information to assist in the appropriate agency's investigation. Occasionally an LCC project may generate data that spawns a separate intensive research study. In operation, this trouble-shooting exercise makes LCC projects small and cost effective.

Activities in 2000-2001

The 2000-2001 operating year saw the majority of LCC program efforts directed at revisiting the Lake Laberge fishery. A consumption advisory for lake trout muscle and burbot liver was placed on the lake in response to research conducted in 1990-1991. A research program conducted in 1991 (Kidd et al. 1993) suggested that the commercial fishing on the lake had altered the foodweb sufficiently to increase the rate of biomagnification in the top lake predators (Kidd et al. 1995, 1998). With the closure of the fishery in 1992, and subsequent changes in fishery management (DeGraff and Mychasiw 1994) the lake trout population has increased to the point where a recent (1999) catch per unit effort study (A. Foos, personal communication) was twice that of the only previous study in 1991. LCC supported a study to collect and analyze lake trout and burbot from Lake Laberge to determine if contaminant levels had changed as a result of this flux in population. A point source of contaminants had been suspected in the 1990-1991 sampling, but one was never identified. Archived samples from other lakes were also analyzed to compare with those obtained from Lake Laberge.

The only other project supported in 2000-2001 through LCC, was a walk-in from the Carmacks Little Salmon First Nation; lake trout had been collected from Mandanna Lake and were provided to the Yukon government Renewable Resources staff for analysis. As a part of the self-government initialization, the Little Salmon First Nation is investigating areas of concern to their community. Mandanna Lake had been identified as possibly being impacted by an unspecified point source pollutant and the lake trout there were suspect in the community. LCC received the fish samples from the Yukon government and sent them for analysis.

All sample results will be incorporated into the Yukon Contaminants Database.

Results

The sample analysis of more recent (2000) tissue samples is not available, but the analysis of archived samples available for Lake Laberge from 1996 and 1998, demonstrated a marked decrease in lipid adjusted concentrations for organochlorines in those samples. These results are presented in Table 1.

Results for the Mandanna Lake samples have not yet been received.

Discussion and Conclusions

A significant drop is indicated in the concentrations of organochlorines in Lake Laberge trout and burbot. A full study recreating the 1991 work with regard to possible changes in trophic position of the lake's top fish predators is needed to determine if the changes are related to the elimination of the commercial fishery and a subsequent rebound of the trout population, or if there is some other agent at work. A study resolving the connection between contaminant levels in the fish and their trophic status in Lake Laberge would bring closure to the search for a point source of contamination to the lake.

The Mandanna trout results should be available shortly and the results communicated the Carmacks Little Salmon First Nation. Procedures are being put in place to insure a more timely delivery of results to LCC stakeholders.

Expected Project Completion Date

The Yukon LCC program is ongoing.

Acknowledgments

The YCC would like to thank the Yukon Territorial Renewable Resource staff for the Mandanna Lake samples and Dr. G. Stern of the Department of Fisheries and Oceans for his interpretation of the sample results.

Table 1. Means (standard deviation) and summary of ANCOVA results used to assess the effects of year to year collections (temporal trends), % lipid and lipid*year interactions (homogeneity of the slope between %lipid and [OC]) of OCs in Lake Laberge burbot liver and trout muscle[1]

	Mean (SD)		% Lipid (Pr)	Lipid*yr (Pr)	R^2 (model)	Lipid adjusted mean		Factor
Burbot	**1996 (n = 10)**	**1999 (n = 11)**				**1996**	**1999**	
% Lipid	33.55 (8.71)	53.77 (17.60)	—	—	—	—	—	—
ΣCBz	52.85 (25.23)	41.58 (17.60)	0.0009	0.9600	0.83	91.49	20.07	4.56 ↓[2]
ΣHCH	54.94 (27.57)	50.25 (23.73)	< 0.0001	0.5928	0.85	104.46	20.96	4.98 ↓
ΣCHL	367.55(177.91)	247.76 (121.83)	0.0003	0.5294	0.93	674.22	111.37	6.05 ↓
ΣDDT	3574.72 (1599.02)	2849.84 (1199.61)	< 0.0001	0.7505	0.89	6230.57	1396.10	4.46 ↓
ΣCHB	3477.67 (1527.68)	3053.46 (1209.41)	< 0.0001	0.4922	0.92	5870.65	1586.66	3.70 ↓
ΣPCB	2131.90 (1015.69)	1625.39 (727.08)	< 0.0001	0.5892	0.90	3792.59	767.91	4.93 ↓
ΣTr-CB	17.92 (9.79)	13.60 (5.54)	< 0.0001	0.3792	0.93	32.12	6.25	5.14 ↓
ΣTe-CB	121.66 (58.41)	89.41 (40.65)	0.0003	0.8241	0.89	220.18	40.86	5.39 ↓
ΣPe-CB	511.47(249.88)	384.47 (166.70)	0.0002	0.6156	0.90	894.13	185.66	4.82 ↓
ΣHx-CB	971.11 (452.11)	697.71 (330.49)	0.0006	0.4533	0.90	1745.02	323.73	2.39 ↓
ΣHp-CB	384.44 (188.81)	245.90 (143.52)	< 0.0001	0.9217	0.92	670.72	168.42	3.98 ↓
ΣOct-CB	105.04 (52.95)	81.20 (37.64)	0.0002	0.6848	0.88	194.02	36.00	5.39 ↓
ΣN-CB	13.77 (6.84)	8.78 (3.77)	0.0009	0.8517	0.95	23.53	4.41	5.33 ↓
Trout	**1996 (n = 8)**	**1998 (n = 7)**				**1996**	**1998**	
% Lipid	10.54 (5.42)	8.98 (3.37)	—	—	—	—	—	—
ΣCBz	6.56 (5.04)	2.06 (0.56)	< 0.0001	0.0851	0.90	4.27	2.20	1.94 ↓
ΣHCH	9.22 (6.98)	1.92 (0.51)	< 0.0001	0.0795	0.88	5.98	2.07	2.89 ↓
ΣCHL	72.78 (54.70)	13.15 (3.62)	< 0.0001	0.1202	0.94	49.85	13.91	3.58 ↓
ΣDDT	320.50 (125.44)	52.66 (14.62)	< 0.0001	0.2556	0.93	278.66	53.97	5.16 ↓
ΣCHB	366.55 (93.62)	70.89 (38.22)	< 0.0001	0.4489	0.92	237.72	67.22	3.54 ↓
ΣPCB	293.44 (196.74)	42.58 (10.52)	< 0.0001	0.1689	0.95	216.62	44.85	4.82 ↓
ΣTr-CB	3.68 (3.05)	0.47 (0.12)	< 0.0001	0.2595	0.89	2.40	0.50	4.80 ↓
ΣTe-CB	24.44 (20.72)	2.45 (0.61)	< 0.0001	0.0735	0.94	15.46	2.62	5.90 ↓
ΣPe-CB	82.17 (59.04)	7.75 (1.91)	< 0.0001	0.0944	0.96	58.14	8.22	7.07 ↓
ΣHx-CB	106.13 (62.25)	16.56 (4.12)	< 0.0001	0.2943	0.97	83.51	17.24	4.84 ↓
ΣHp-CB	61.24 (39.86)	11.92 (2.93)	< 0.0001	0.1596	0.90	45.26	12.66	3.58 ↓
ΣOct-CB	11.67 (8.53)	2.82 (0.71)	< 0.0001	0.1512	0.92	8.26	2.98	2.77 ↓
ΣN-CB	3.33 (3.13)	0.43 (0.11)	< 0.0001	0.0725	0.90	1.93	0.46	4.19 ↓

[1] All concentrations are in $ng.g^{-1}$

[2] Significant increase (↑) or decrease (↓) in the adjusted means of major OC groups ($p < 0.05$).

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Risk Characterization of Arsenic Exposure from Consumption of Berries in the Akaitcho Territory

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Abstract

This project is a follow-up to a previous study investigating arsenic in berries which found elevated levels in berries on mine sites. This study used exposure and dietary information from the previous study, and determined the type of arsenic present and its bioavailability. From this, risks to consumers from arsenic in berries were assessed and found to be minimal.

Key Project Message

- Arsenic (As) in berries does not pose a significant health risk to consumers.

Objectives

Overall

- Characterize the risk of exposure to As from harvesting and consuming berries collected from the Akaitcho territory.

Specific

1. Estimate the dietary exposure dose using dietary data collected in the Yellowknife Back Bay Study and As concentrations in berries collected from the Akaitcho in 1998.
2. Characterize the speciation As in six species of berries.

3. Determine the bioavailability of As in soil samples by measuring selected soil chemical properties such as pH, organic matter content, available phosphorus and the content of iron oxides, in addition to measurements of total As in the soils, and organic and inorganic forms of As in the soil solutions.

Introduction

Analysis of berries collected from the Akaitcho Territory in 1998 showed elevated levels of As. The U.S. Environmental Protection Agency (EPA) and the International Agency for Research on Cancer (IARC) classify As as a human carcinogen. Chemical speciation affects properties such as toxicity, biological uptake and fate, which is best illustrated by the inorganic and organic form of As. The organic forms of As are usually less toxic than the inorganic forms. There are no existing data on As speciation in terrestrial plants. It is, therefore, important to determine what is the As speciation in berries consumed by people in the Akaitcho Territory, particularly those berries with high concentrations.

Activities in 2000-2001

The average and high-end exposure concentrations of As from the consumption of berries were estimated using the dietary information collected from the Back Bay Study and the Dene/Metis Dietary Survey conducted by the Centre for Indigenous Peoples' Nutrition and Environment (Receveur et al. 1996).

Speciation of As in 12 berry samples collected in 1998 was conducted by the Food Research Division of Health Canada. A method for total inorganic arsenic, As(III) + As(V) (the most toxic forms), in seaweed developed in the Food Research Division was modified for analysis of berries. The method involves solvent extraction of the berries with halide followed by back-extraction and determination by graphite-furnace atomic absorption spectrometry (AAS).

A total of 52 soil samples collected from the previous year were digested using $HNO_3/HClO_4$ and analysed by AAS. Standard techniques were used to measure pH, organic matter content, cation exchange capacity, and the content of iron (Fe), aluminum (Al), manganese (Mn), and silicon (Si) oxides. Deionized distilled water was used to extract soil solutions, which were analysed for total dissolved As by AAS and As (III+V) by hydride generation coupled with AAS (HG-AAS).

Results

The average berry consumption is estimated to be 3108 $g \cdot person^{-1} \cdot year^{-1}$. Intake of inorganic As from berries collected from the mining area will be 3108 g × 0.162 $\mu g \cdot g^{-1}$ ÷ 70 kg ÷ 365 days, or 0.02 $\mu g \cdot kg^{-1} \cdot day^{-1}$ (assuming average body weight of 70 kg). Assuming the high berry intake group consumed the mean amount plus two standard deviations of berries, or 9324 g, inorganic As intake would be 0.059 $\mu g \cdot kg^{-1} \cdot day^{-1}$. Both of these intake levels are lower than the guideline levels for inorganic As (Agency for Toxic Substances and Disease Registry 1999) (Table 1). Therefore, the risk for non-carcinogenic endpoints of oral intake of As from berries is minimal.

Using the Cancer Slope Factor of the U.S. Environmental Protection Agency for As of 1.75 $mg \cdot kg^{-1} \cdot day^{-1}$ (Integrated Risk Information System 1992), the excess lifetime cancer risk for As intake for average berry consumers will be 3.5×10^{-5} and 1.1×10^{-4} for the high end consumers. The cancer risk can be described as low (New York State Department of Health 1995).

Discusion and Conclusions

The average yearly berry consumption in the Akaitcho Territory is estimated to be 3108 $g \cdot person^{-1} \cdot year^{-1}$ (CV = 100%). The highest As concentration was 1.9 $\mu g \cdot g^{-1}$ found in raspberries collected from near the Giant Mine site. Approximately one-third of As in the berries was found to be inorganic.

Table 1. Comparison of arsenic intake to guideline levels for non-carcinogenic endpoints

Inorganic As intake ($\mu g \cdot kg^{-1} \cdot day^{-1}$)	Guideline	Authority
2	Tolerable daily intake	World Health Organization
2	Tolerable daily intake	Health Canada
0.3	Maximal residual level	Agency for Toxic Substances and Disease Registry
0.3	Reference dose	U.S. Environmental Protection Agency
0.02	Average intake from berries from mines	
0.059	High-end intake from berries from mines	

Average and high-end inorganic As intake are estimated to be 0.02 and 0.059 $\mu g \cdot kg^{-1} \cdot day^{-1}$, respectively. The intake levels are lower than the guideline levels, suggesting that the risk for non-carcinogenic endpoints as a result of berry consumption is minimal. The excess lifetime cancer risk for As intake for average berry consumers is estimated to be 3.5×10^{-5} and 1.1×10^{-4} for the high-end consumers. The cancer risk can be described as low.

The soil data suggests that As in the soil was bioavailable for plant uptake.

Because of the many varieties of berries and their seasonality, and individual differences in consumption patterns, it is difficult to accurately assess consumption levels. Erring on the side of caution, this study still suggests that levels of As in berries studied are low enough to enable consumers to eat up to one cup of berries every day year-round with no significant health risks.

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1999 Peel River Fish Contaminant Study

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Abstract

Due to the continuing concerns of residents from Fort McPherson, Northwest Territories, about the safety of eating fish from the Peel River, a baseline study to determine the extent and type of possible contaminants present was conducted in 1999. A total of 30 fish, including 10 each of inconnu (*Stenodus leucichthys*), broad whitefish (*Coregonus nasus*) and burbot (*Lota lota*), were examined for a suite of heavy metals and organochlorines. All fish were captured by local fishermen at traditional fishing sites along the Peel River. Analysis shows that cadmium and lead levels were below detectable limits among all three species. Broad whitefish had the lowest quantities of heavy metals. The largest inconnu examined had an elevated mercury level. Two inconnu and one burbot had arsenic levels that exceeded consumption guidelines recommended by Agriculture and Agri-Food Canada and Health Canada. Organochlorines were typically at low levels in inconnu and broad whitefish. Only burbot possessed high toxaphene levels and recommendations are made as to the safe amount that can be consumed per week. Because burbot are mainly eaten seasonally, it is unlikely that short-term consumption will cause a health risk. Based on the results of this study, these fish species from the Peel River are safe to eat. No additional study is required at this time.

Key Project Message

- This study indicates that inconnu, broad whitefish and burbot from the Peel River are safe to eat.

Objectives

1. Address local concerns about the safety of consuming specific fish species that form the mainstay of the local diet.
2. Determine the occurrence and geographic distribution of organochlorines (OCs) and metals in fish species that are consumed as traditional/country foods by residents in the Peel and Arctic Red River watersheds.
3. Compare the results from this study with those previously gathered in the area.
4. Provide baseline data on the contaminant levels in fish from the Peel and Arctic Red River watersheds.

Introduction

Residents of Fort McPherson, Northwest Territories have voiced concerns about the condition of fish from the Peel River on numerous occasions. An abandoned Shell Oil exploration site and possible point source of contaminants upstream has been the main cause for these concerns. Although the dump site has been gradually cleaned up over the past years, the residents remain concerned about possible long-term affects on fish quality. Therefore, a contaminant study of fish from the Peel River was undertaken to address questions about the health risks associated with eating these fish. Additionally, there have been only limited studies of fish from the Peel River and, thus, almost any study on fish from the area would act as a baseline against which future changes could be measured.

Activities in 2000-2001

Ten inconnu (*Stenodus leucichthys*), 10 broad whitefish (*Coregonus nasus*) and 10 burbot (*Lota lota*) were collected from the Peel River by Fort McPherson fishermen in late 1999. All fish were weighed and measured, sex was determined and ageing tissues were removed. Muscle tissue was removed from inconnu and whitefish. Livers were also sampled from burbot. These three species were selected for contaminant analysis because the Gwich'in Harvest Study (McDonald 1998) shows they are widely consumed by residents of the Fort McPherson area.

All fish were tested for the presence of heavy metals (arsenic, cadmium, lead and mercury) and OCs, including PCBs and chlorinated pesticides. Testing was carried out by the Centre for Indigenous Peoples' Nutrition and Environment (CINE) at McGill University.

A report on the results was produced and submitted to the Northern Contaminants Program and residents of Fort McPherson, Northwest Territories (Snowshoe and Stephenson 2000).

Results

Otolith-determined ages, fork length (total length for burbot), weight and sex of sampled fish are presented in Table 1.

Complete results of all heavy metals results are presented in Table 2. Cadmium and lead levels were either below detectable levels or very low in all sampled fish. DDT and PCB levels in all fish were either below detectable levels or very low. Complete results from all OCs measured are presented in Table 3.

Table 1. Summary of biological information for fish collected from the Peel River in 1999 for contaminant analyses

Fish #	Species	Length (mm)	Weight (g)	Age	Sex
1	Inconnu	800	4000[1]	N/A[2]	N/A
2	Burbot	690	2750	13	F
3	Burbot	660	2250	13	M
4	Burbot	590	2000	12	F
5	Burbot	700	2500	15	F
6	Burbot	700	1900	12	M
7	Burbot	810	3100	13	M
8	Burbot	650	2000	9	F
9	Burbot	630	1950	13	M
10	Burbot	660	2050	14	M
11	Burbot	480	1200	9	N/A
12	BWF[3]	460+[4]	1700	10	M
13	BWF	460	1600	N/A	F
14	BWF	460	2250	11	F
15	BWF	580	3300	9	F
16	BWF	600	2800	12	F
17	BWF	570	2150	N/A	M
18	BWF	540	2000	8	M
19	Inconnu	650	2500	8	M
20	Inconnu	750	3500	11	M
21	Inconnu	770	3500	11	M
22	Inconnu	800	3950	14	M
23	Inconnu	800	4000	16	M
24	Inconnu	990	6800	23	M
25	Inconnu	770	3000	8	M
26	BWF	560	2000	12	M
27	Inconnu	780	3850	15	M
28	Inconnu	690	2800	12	M
29	BWF	470+[4]	1800	12	M
30	BWF	460+[4]	2100	N/A	M

[1] Fish was dressed prior to sampling.

[2] Indeterminant age or sex

[3] Broad whitefish

[4] Incomplete measurement due to damaged tail

Table 2. Heavy metal concentrations ($\mu g \cdot 100\ g^{-1}$) in Peel River fish samples, 1999

Fish #	Species	Tissue	Arsenic	Cadmium	Lead	Mercury
1	Inconnu	flesh	BDL[1]	BDL	3.9	**53.5**[2]
2	Burbot	liver	23.0	2.0	BDL	3.6
3	Burbot	liver	33.6	4.4	BDL	6.1
4	Burbot	liver	56.7	1.5	BDL	3.0
5	Burbot	liver	60.6	3.5	BDL	5.2
6	Burbot	liver	29.2	2.8	BDL	4.3
7	Burbot	liver	**404.0**	2.2	BDL	7.2
8	Burbot	liver	43.6	3.0	BDL	2.1
9	Burbot	liver	2.8	12.2	BDL	4.9
10	Burbot	liver	52.7	9.5	BDL	3.0
11	Burbot	liver	118.2	2.5	BDL	4.6
12	BWF	flesh	BDL	BDL	BDL	3.7
13	BWF	flesh	BDL	BDL	BDL	7.3
14	BWF	flesh	BDL	BDL	BDL	18.4
15	BWF	flesh	BDL	BDL	BDL	8.8
16	BWF	flesh	BDL	BDL	BDL	8.1
17	BWF	flesh	BDL	BDL	BDL	15.9
18	BWF	flesh	BDL	BDL	5.5	6.6
19	Inconnu	flesh	BDL	BDL	3.5	28.4
20	Inconnu	flesh	BDL	BDL	8.0	37.1
21	Inconnu	flesh	BDL	BDL	5.4	28.8
22	Inconnu	flesh	73.3	BDL	3.5	33.8
23	Inconnu	flesh	**312.4**	BDL	6.8	21.5
24	Inconnu	flesh	203.3	BDL	BDL	24.3
25	Inconnu	flesh	2.8	BDL	7.8	35.0
26	BWF	flesh	2.3	BDL	8.0	3.8
27	Inconnu	flesh	**324.7**	BDL	9.6	35.3
28	Inconnu	flesh	5.4	BDL	12.6	19.0
29	BWF	flesh	1.1	BDL	8.0	3.8
30	BWF	flesh	3.4	BDL	3.5	5.5
Guideline $\mu g \cdot 100\ g^{-1}$			**300**	**100**	**200**	**50**

[1] Below detectable limits

[2] Numbers in bold exceed Agriculture and Agri-Food Canada and Health Canada guidelines.

Broad whitefish

Broad whitefish had very low levels of all metals. Organochlorine levels were also typically lower than those found in inconnu or burbot.

Inconnu

One inconnu had a high mercury level, but this fish was one of the largest and oldest fish of all inconnu sampled. Two inconnu had arsenic levels slightly higher than the consumption guidelines recommended by Agriculture and Agri-Food Canada and Health Canada. Organochlorine levels in all inconnu were typically low.

Burbot

One burbot (the largest sampled) had an arsenic level that exceeded consumption guidelines used by Agriculture and Agri-Food Canada and Health Canada. Burbot were the only fish that exhibited some high OC levels (mainly toxaphene). Although some of these levels were high and exceeded the tolerable daily intake limits, they should not pose a risk to anyone eating burbot or their livers because burbot are mainly eaten seasonally and consumption at these levels for a short period of time should not cause health problems.

Discussion

Contaminants are present to some degree in all fish from all locations within the Northwest Territories and other parts of Canada, so these local results are not unexpected. Basically, it means that the fish sampled from the Peel River are largely safe to eat.

Due to the processes of biomagnification and bioaccumulation, the largest fish examined usually had the greatest amount of contaminants. People who are greatly concerned about contaminants could reduce their intake simply by eating smaller fish. Overall, fish are one of the best traditional foods and there is little evidence that eating fish from the Peel River is harmful.

Based on the results from this study, CINE has recommended that no further studies of fish from the Peel River are required at this time.

Project Completion Date

December 2000

Table 3. Major organochlorine concentrations[1] (ng·g^{-1}) in Peel River fish samples, 1999

Sample #	Species	Tissue	CHL	CBZ	DDT	HCH	MIR	HE	PCB	TOX
1	Inconnu	Flesh	3	1	21	0[2]	0	0	1	68
2	Burbot	Liver	6	2	44	1	3	0	3	75
3	Burbot	Liver	16	6	31	3	2	5	24	97
4	Burbot	Liver	2	7	14	2	0	2	9	253
5	Burbot	Liver	7	3	23	2	2	2	12	75
6	Burbot	Liver	3	3	15	2	0	1	5	173
7	Burbot	Liver	6	2	17	2	3	1	8	348
8	Burbot	Liver	9	4	22	2	1	3	14	151
9	Burbot	Liver	27	5	39	1	6	8	45	201
10	Burbot	Liver	7	3	15	1	3	2	15	136
11	Burbot	Liver	4	4	14	1	9	1	5	148
12	BWF	Flesh	1	0	13	0	0	0	4	106
13	BWF	Flesh	2	1	11	0	2	0	0	99
14	BWF	Flesh	2	0	11	0	01	0	1	74
15	BWF	Flesh	2	0	15	0	0	0	1	42
16	BWF	Flesh	2	0	12	0	0	0	0	30
17	BWF	Flesh	1	1	10	0	1	0	0	83
18	BWF	Flesh	2	0	18	0	0	0	0	45
19	Inconnu	Flesh	2	0	8	0	0	0	1	66
20	Inconnu	Flesh	2	1	18	0	0	0	1	68
21	Inconnu	Flesh	2	1	13	0	0	0	2	34
22	Inconnu	Flesh	2	1	15	0	1	0	1	86
23	Inconnu	Flesh	3	1	11	0	1	0	2	85
24	Inconnu	Flesh	4	1	9	0	0	0	3	69
25	Inconnu	Flesh	1	0	6	0	2	0	1	44
26	BWF	Flesh	1	0	15	1	2	0	0	28
27	Inconnu	Flesh	2	1	10	0	0	0	1	51
28	Inconnu	Flesh	1	0	7	0	0	0	0	30
29	BWF	Flesh	1	0	13	0	0	0	0	21
30	BWF	Flesh	1	0	7	1	0	0	0	21
Guideline μg·100 g^{-1}			**N/A[3]**	**300**	**5000**	**N/A**	**100**	**N/A**	**2000**	**N/A**

[1] CHL = chlordane, CBZ = chlorobenzene, DDT = dichlorodiphenyltrichloroethane, HCH = hexachlorocyclohexane, MIR = mirex, HE = heptachlor epoxide, PCB = polychlorinated biphenyls, TOX = toxaphene.

[2] Below detectable limits (< 0.1 ng·g^{-1}) or completely absent.

[3] No Agriculture and Agri-Food Canada and Health Canada guidelines for this compound.

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Mercury Levels in Fish from Lakes in the Dogrib Region Surrounding Rae Lakes

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Abstract

This study investigated the presence of mercury and other metals in fish from two lakes in the Dogrib region surrounding Rae Lakes, Northwest Territories. In each lake, 10 muscle and liver samples were obtained from each lake trout (*Salvelinus namaycush*) and round whitefish (*Prosopium cylindraceum*). Each fish was weighed, measured for fork length, and sampled for aging structures (otoliths) to evaluate the relationship between age/size and levels of mercury in the fish. The metal levels measured in the fish were compared with levels that are considered safe for consumption. Many of the metals were found to be in low concentration and below detection limits. In both lakes, mean mercury levels in lake trout muscle and liver were higher than in round whitefish. Some lake trout in both lakes had muscle or liver mercury levels that exceeded the levels recommended by the Canadian guidelines for chemical contaminants in fish.

Key Project Messages

1. Most metals (e.g. cadmium, cobalt, lead, iron, arsenic) in whitefish and lake trout from two lakes in the Dogrib region surrounding Rae Lakes, Northwest Territories (NWT), were found to be below detection limits and/or in low concentration.
2. Lake trout had mean mercury (Hg) levels in both muscle and liver that are higher than those found in round whitefish.
3. Several lake trout had muscle or liver tissue Hg levels that exceeded the levels recommended by the Canadian guidelines for chemical contaminants in fish.

Objectives

1. Obtain baseline data on the levels of Hg and other metals in fish from lakes that are commonly used as traditional harvesting grounds in the Dogrib region surrounding Rae Lakes, NWT.
2. Evaluate the levels of Hg found in fish in terms of the size/age relationship.
3. The long-term objective is to establish an integrated monitoring program to identify contaminant levels in fish on a lake-by-lake basis.

Introduction

The community of Rae Lakes, NWT has prepared an environmental strategy to undertake a study on the levels of Hg and other metals in fish commonly consumed by local residents. This work is required due to a concern that past development in the region may have had an effect on the natural resources of the area.

Recent studies have shown that Hg levels in fish from a number of lakes in the Northwest Territories have exceeded the levels for normal human consumption (e.g. see Jensen et al. 1997 for a summary of human health risk assessments in the Canadian North). To date, little to no work has been done to determine these levels in the Dogrib region. This study is intended to be a starting point for identifying regional contaminant levels in key indicator fish species.

Activities

Rae Lakes (64°5' N, 117°17' W) and Faber Lake (64°0' N, 117°15' W) were identified from the Rae Lakes region, as the two lakes that would be used to investigate the presence of Hg and other metals in fish. Field sampling of these two lakes was carried out during the summer of 2000. Nets with a mesh size of 10 to 11.5 cm were used to obtain the round whitefish and the lake trout were obtained by trolling.

In each lake, 10 muscle and liver samples were obtained from each lake trout and round whitefish. Each fish was weighed (kg), measured for fork length (mm), and sampled for aging structures (otolith) to evaluate the age/size relationship as it pertains to levels of Hg in the fish. All samples were collected and processed according to the guidelines outlined in the British Columbia Field Sampling Manual (British Columbia Ministry of Environment, Lands and Parks, 1996). All samples were individually stored in labeled plastic bags and kept frozen until analysis. Taiga Environmental Laboratory in Yellowknife conducted the metals analysis on muscle and liver tissues. Total Hg was measured in both muscle and liver; arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel and zinc were measured in muscle only. Fish aging analysis was conducted by Mr. G. Carder.

Results

The metal concentrations in the lake trout and round whitefish from Rae Lakes are presented in Tables 1 and 2. The metal concentrations in the lake trout and round whitefish from Faber Lake are presented in Tables 3 and 4. The arithmetic mean and standard deviation were calculated and are presented in these tables.

The arithmetic mean arsenic level in Rae Lakes lake trout muscle samples was $0.47 \pm 0.15\ \mu g \cdot g^{-1}$. The arithmetic mean arsenic level in Rae Lakes round whitefish muscle samples was $0.42 \pm 0.15\ \mu g \cdot g^{-1}$. The arithmetic mean arsenic level in Faber Lake lake trout muscle was $0.6 \pm 0.4\ \mu g \cdot g^{-1}$. The arithmetic mean arsenic level in Faber Lake round whitefish muscle samples was $0.6 \pm 0.2\ \mu g \cdot g^{-1}$. The Canadian guidelines for chemical contaminants in fish, established by the Canadian Food Inspection Agency, recommend that arsenic concentrations in fish be below $3.5\ \mu g \cdot g^{-1}$.

Lead was below detection limits in all the Rae Lakes lake trout muscle samples and in all but two whitefish samples. Lead was below detection limits in all but two of the Faber Lake lake trout muscle samples and in all Faber Lake round whitefish muscle samples. The Canadian guidelines for chemical contaminants in fish, established by the Canadian Food Inspection Agency, recommend that lead concentrations in fish be below $0.5\ \mu g \cdot g^{-1}$.

The arithmetic mean Hg levels in Rae Lakes lake trout muscle and liver samples were $0.46 \pm 0.14\ \mu g \cdot g^{-1}$ and $0.82 \pm 0.31\ \mu g \cdot g^{-1}$, respectively. The arithmetic mean Hg levels in Rae Lakes round whitefish muscle and liver samples were $0.08 \pm 0.03\ \mu g \cdot g^{-1}$ and $0.15 \pm 0.07\ \mu g \cdot g^{-1}$, respectively. The arithmetic mean Hg levels in Faber Lake lake trout muscle and liver samples were $0.35 \pm 0.07\ \mu g \cdot g^{-1}$ and $0.59 \pm 0.17\ \mu g \cdot g^{-1}$, respectively. The arithmetic mean Hg levels in Faber Lake round whitefish muscle and liver samples were $0.1 \pm 0.02\ \mu g \cdot g^{-1}$ and $0.2 \pm 0.06\ \mu g \cdot g^{-1}$, respectively. The Canadian guidelines for chemical contaminants in fish, established by the Canadian Food Inspection Agency, recommend that Hg concentrations in fish for commercial sale be below $0.5\ \mu g \cdot g^{-1}$ and below $0.2\ \mu g \cdot g^{-1}$ for subsistence use.

Discussion and Conclusions

The levels of cadmium, cobalt, lead and iron in lake trout and round whitefish from Rae Lakes and Faber Lake were, in most cases, at or below detection limits. The round whitefish in both lakes had levels of Hg, arsenic and lead below values used to regulate the sale of commercial fish and below levels recommended for subsistence use in the case of Hg. The lake trout in both lakes also had arsenic and lead values below those used to regulate the sale of commercial fish.

Table 1. **Metal concentration ($\mu g \cdot g^{-1}$), weight (kg), fork length (mm) and age (years) of Rae Lakes lake trout**[1]

Sample ID	Weight (kg)	Fork length (mm)	Otolith (years)	Moisture content (%)	Mercury ($\mu g \cdot g^{-1}$) muscle	Arsenic ($\mu g \cdot g^{-1}$)	Chromium ($\mu g \cdot g^{-1}$)	Copper ($\mu g \cdot g^{-1}$)	Iron ($\mu g \cdot g^{-1}$)	Manganese ($\mu g \cdot g^{-1}$)	Nickel ($\mu g \cdot g^{-1}$)	Zinc ($\mu g \cdot g^{-1}$)	Mercury ($\mu g \cdot g^{-1}$) liver
RL LT1	1.804	549	7	72.7	0.48	< 0.3	< 0.3	0.8	< 30	0.2	< 0.1	10	0.68
RL LT2	2.07	583	CA[2]	80.2	0.54	< 0.3	< 0.3	1	< 30	0.5	< 0.1	12	1.1
RL LT3	1.986	545	14	78.5	0.22	< 0.3	0.3	1.3	< 30	0.4	0.1	11	0.23
RL LT4	1.908	568	13	78.7	0.46	0.3	0.3	1.2	< 30	0.4	0.1	10	0.67
RL LT5	1.808	565	17	78.2	0.43	0.6	< 0.3	1.1	< 30	0.4	< 0.1	11	0.55
RL LT6	2.614	590	CA	77.8	0.41	< 0.3	0.5	1.4	41	0.4	< 0.1	14	0.93
RL LT7	1.75	550	21	79.2	0.75	0.5	< 0.3	1	< 30	0.3	0.1	12	1.26
RL LT8	1.894	465	21	82.7	0.31	< 0.3	< 0.3	1	< 30	0.3	0.1	17	0.65
RL LT9	2.274	579	CA	77.7	0.46	< 0.3	0.3	0.9	< 30	0.3	0.1	10	0.98
RL LT10	1.78	542	13	78.3	0.54	< 0.3	< 0.3	1.3	< 30	0.3	0.2	12	1.1
Mean				78.4	0.46	0.47	0.35	1.1	41	0.35	0.12	11.9	0.82
Standard Deviation				2.6	0.14	0.15	0.1	0.22		0.08	0.04	2.2	0.31

[1] The following metals were below detection limits (in brackets) in all samples: cadmium (0.1 $\mu g \cdot g^{-1}$), cobalt (0.1 $\mu g \cdot g^{-1}$) and lead (0.1 $\mu g \cdot g^{-1}$).

[2] Could not age

The lake trout in both lakes had mean Hg levels in both muscle and liver tissue samples that are higher than those found in round whitefish. Several lake trout in both lakes had muscle or liver tissue Hg levels that exceeded the levels recommended by the Canadian guidelines for chemical contaminants in fish. The recommended Hg concentration in fish is below 0.5 $\mu g \cdot g^{-1}$ for commercial sale and below 0.2 $\mu g \cdot g^{-1}$ for subsistence use. This study used a relatively small sample size (10 lake trout from each lake) and further research is needed to determine if the Hg levels are significantly higher than the recommended levels.

The provisional tolerable daily intake for zinc, copper and iron are 0.3 to 1.0 $mg \cdot kg^{-1}$ b/w (body weight/day), 0.05 to 0.5 $mg \cdot kg^{-1}$ b/w and 0.8 $mg \cdot kg^{-1}$ b/w, respectively (Joint Expert Committee on Food Additives 1999). The estimated daily intake (EDI) for chromium is 50 $\mu g \cdot day^{-1}$ and the EDI for cobalt is 40 to 50 $\mu g \cdot day^{-1}$ (Seiler and Sigel 1988). Many guidelines for safe consumption of a particular fish depend on the level of metal in the tissue; the quantity of fish consumed each week and an individual's body weight. The results of this study only determined the mean concentration of metals in fish. More research is needed to determine if these fish, at their present consumption level, pose a health risk to the residents.

Project Completion Date

The project sampling was completed in September 2000. The results will be further interpreted to evaluate the age/size relationship as it pertains to levels of Hg and other metals in the fish.

Acknowledgments

We would like to thank Carey Bonnell, Resource Manager at GFNB, in the months preceding this study, for his initial proposal, and Gary Carder who conducted the fish aging analysis.

Table 2. Metal concentration ($\mu g \cdot g^{-1}$), weight (kg), fork length (mm) and age (years) of Rae Lakes whitefish[1]

Sample ID	Weight (kg)	Fork length (mm)	Otolith (years)	Moisture content (%)	Mercury ($\mu g \cdot g^{-1}$) muscle	Arsenic ($\mu g \cdot g^{-1}$)	Cobal ($\mu g \cdot g^{-1}$)	Chromium ($\mu g \cdot g^{-1}$)	Copper ($\mu g \cdot g^{-1}$)	Iron ($\mu g \cdot g^{-1}$)	Manganese ($\mu g \cdot g^{-1}$)	Nickel ($\mu g \cdot g^{-1}$)	Lead ($\mu g \cdot g^{-1}$)	Zinc ($\mu g \cdot g^{-1}$)	Mercury ($\mu g \cdot g^{-1}$) liver
RLWF1	1.724	485	CA[2]	76.8	0.03	0.4	< 0.1	< 0.3	0.7	< 20	0.5	< 0.1	< 0.1	14	0.09
RLWF2	1.86	484	9	74.8	0.07	0.4	< 0.1	0.3	0.8	< 20	0.5	0.1	< 0.1	13	0.12
RLWF3	1.474	455	CA	76.8	0.06	0.7	0.1	0.7	0.8	24	0.5	0.1	0.6	12	0.14
RLWF4	2.012	480	8	75.9	0.06	< 0.3	0.1	< 0.3	0.6	< 20	0.3	0.1	0.1	11	0.06
RLWF5	1.344	451	7	77.6	0.08	0.3	< 0.1	0.3	1	< 20	0.4	0.1	< 0.1	13	0.17
RLWF6	1.136	450	7	78.5	0.1	0.4	< 0.1	1.3	0.9	< 20	0.7	0.2	< 0.1	14	0.15
RLWF7	1.862	482	6	75.2	0.08	< 0.3	< 0.1	0.5	0.9	< 20	0.4	0.1	< 0.1	13	0.14
RLWF8	1.246	492	9	77	0.07	< 0.3	0.1	0.4	1	< 20	0.4	0.1	< 0.1	14	0.09
RLWF9	1.916	500	10	75.9	0.13	< 0.3	0.1	0.4	2.1	< 20	0.4	0.3	< 0.1	13	0.17
RLWF10	1.352	456	12	79.4	0.13	0.3	< 0.1	0.7	0.9	< 20	0.4	0.1	< 0.1	12	0.32
Mean				76.8	0.08	0.42	0.1	0.58	0.97	24	0.45	0.13	0.35	12.9	0.145
Standard Deviation				1.4	0.03	0.15	0	0.33	0.42		0.12	0.071	0.35	0.994	0.07

[1] Cadmium was below the detection limit (0.1 $\mu g \cdot g^{-1}$) (in brackets) in all samples.

[2] Could not age

Table 3. Metal concentration (μg·g⁻¹), weight (kg), fork length (mm) and age (years) of Faber Lake lake trout[1]

Sample ID	Weight (kg)	Fork length (mm)	Otolith (years)	Moisture content (%)	Mercury (μg·g⁻¹) muscle	Arsenic (μg·g⁻¹)	Cobal (μg·g⁻¹)	Chromium (μg·g⁻¹)	Copper (μg·g⁻¹)	Iron (μg·g⁻¹)	Manganese (μg·g⁻¹)	Nickel (μg·g⁻¹)	Lead (μg·g⁻¹)	Zinc (μg·g⁻¹)	Mercury (μg·g⁻¹) liver
FLLT1	1.232	506	11	78.4	0.3	< 0.3	< 0.1	< 0.3	1.3	< 30	0.2	< 0.1	<0.1	11	0.52
FLLT2	3.004	655	25	80	0.41	1.4	< 0.1	< 0.3	0.9	< 30	0.3	0.1	< 0.1	11	0.72
FLLT3	1.352	469	12	80	0.35	0.5	0.1	< 0.3	1.2	< 30	0.4	0.1	0.1	11	0.51
FLLT4	0.828	451	9	78.2	0.2	1	< 0.1	0.3	1.3	< 30	0.3	0.1	< 0.1	12	0.24
FLLT5	1.736	552	22	78.6	0.44	0.3	< 0.1	< 0.3	1.1	< 30	0.4	0.1	0.1	12	0.52
FLLT6	1.834	578	17	78.3	0.36	< 0.3	< 0.1	< 0.3	1.3	< 30	0.3	< 0.1	< 0.1	11	0.75
FLLT7	1.368	505	14	80.5	0.33	0.8	< 0.1	< 0.3	1.8	31	0.3	0.2	< 0.1	15	0.56
FLLT8	1.572	543	10	78	0.36	0.3	< 0.1	< 0.3	1.2	< 30	0.3	0.2	< 0.1	12	0.8
FLLT9	1.99	562	14	78.4	0.35	0.5	< 0.1	< 0.3	1.6	< 30	0.3	< 0.1	< 0.1	11	0.58
FLLT10	1.74	568	13	78	0.42	0.4	< 0.1	< 0.3	1.5	< 30	0.3	< 0.1	< 0.1	11	0.74
Mean				78.8	0.35	0.6	0.1	0.3	1.3	31	0.3	0.13	0.1	11.7	0.59
Standard Deviation				0.94	0.07	0.4			0.3		0.06	0.05	0	1.3	0.17

[1] Cadmium was below the detection limit (0.1 μg·g⁻¹) (in brackets) in all samples.

Table 4. Metal concentration (µg·g^{-1}), weight (kg), fork length (mm) and age (years) of Faber Lake whitefish[1]

Sample ID	Weight (kg)	Fork length (mm)	Otolith (years)	Moisture content (%)	Mercury (µg·g^{-1}) muscle	Arsenic (µg·g^{-1})	Chromium (µg·g^{-1})	Copper (µg·g^{-1})	Manganese (µg·g^{-1})	Nickel (µg·g^{-1})	Zinc (µg·g^{-1})	Mercury (µg·g^{-1}) liver
FL WF1	1.944	503	9	78.1	0.1	0.3	< 0.3	0.7	0.4	< 0.1	11	0.16
FL WF2	1.466	488	CA[2]	77.7	0.09	0.6	< 0.3	1.5	0.4	0.1	12	0.23
FL WF3	1.57	459	9	79.7	0.12	< 0.3	0.5	0.8	1.0	0.2	10	0.28
FL WF4	1.432	450	10	77	0.13	0.7	< 0.3	0.9	0.4	< 0.1	11	0.21
FL WF5	1.863	521	12	79.5	0.1	0.7	0.3	0.6	0.8	0.2	11	0.16
FL WF6	1.27	455	12	77.2	0.09	0.6	0.3	0.6	0.6	0.1	11	0.13
FL WF7	1.072	445	11	69.3	0.08	< 0.3	< 0.3	0.4	0.5	< 0.1	10	0.16
FL WF8	1.3	505	11	78.5	0.09	0.5	< 0.3	0.8	0.7	0.1	11	0.18
FL WF9	1.526	484	10	78.4	0.13	0.3	0.3	0.7	0.7	0.1	10	0.3
FL WF10	1.664	500	11	78.9	0.07	0.9	0.4	0.7	0.6	< 0.1	11	0.16
Mean x				77.4	0.1	0.6	0.36	0.77	0.61	0.13	10.8	0.2
Standard Deviation				3	0.02	0.2	0.09	0.29	0.2	0.05	0.63	0.06

[1] The following metals were below detection limits (in brackets) in all samples: cadmium (0.1 µg·g^{-1}), cobalt (0.1 µg·g^{-1}), iron (30 µg·g^{-1}) and lead (0.1 µg·g^{-1})

[2] Could not age

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Education and Communications

Inuvialuit Regional Corporation Contaminants Coordinator: a Five-Year Strategy of Communication and Action on Contaminant Issues in the Canadian Arctic

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Abstract

The objective of the Inuvialuit Regional Corporation Regional Contaminants Coordinator (RCC) position is to provide the Inuvialuit with a better understanding about the presence of contaminants within the Inuvialuit Settlement Region (ISR), how they enter the food chain, and their possible effects on wildlife and the Inuvialuit population. The RCC is in constant communication with community members and organizations, and works with scientists and researchers to determine what work is required for the future to better understand contaminants issues in the ISR, and to be able to answer questions and concerns raised by Inuvialuit on these issues. Through this network, stronger communication links among communities, schools, the Northern Contaminants Program, and industry have been built. The RCC was involved in the Inuvialuit Community Tour in January 2001, which visited all ISR communities and discussed their concerns on health and contaminant issues. In general, all communities had questions about contaminants, global warming and the oil and gas industry/development. With the introduction of the ISR RCC, apprehension, mistrust and alarm over contaminants information among community members have been somewhat mitigated, because someone from their region can explain contaminants in plain language and in their own language.

Key Project Messages

1. Communities within the Inuvialuit Settlement Region (ISR) have a broad range of concerns related to contaminants and their effects on wildlife and human health in the ISR. It is important that there be an ongoing, coordinated exchange of information and research results among researchers, project managers and community members.
2. A monitoring program for the ISR is necessary to identify contaminants within the region and their impact on the wildlife and human population.
3. Several management plans related to wildlife and the environment have been developed through the efforts of the co-management boards established under the Inuvialuit Final Agreement. These plans provide guidance to the agencies responsible for the overall management of the region's wildlife and environment. The identification of contaminants within the ISR and their impact on the wildlife and human population of the region is required to help monitor the impacts and was therefore added to these management plans. These issues could be addressed through a monitoring program for the ISR.

Objectives

1. Achieve an appropriate level of understanding among the Inuvialuit about the presence of contaminants within the ISR, how they enter the food chain and their effects on wildlife and the health of the Inuvialuit population.
2. Understand the questions and concerns Inuvialuit have in relation to contaminant issues within the ISR and beyond.
3. Facilitate interactions within and among Inuvialuit communities with regard to contaminant issues and, in turn, to facilitate interactions among communities, the Northern Contaminants Program (NCP) and research program managers.
4. Build capacity and partnership at the community level to effectively communicate community concerns and priorities, with regard to contaminants, to decision-making bodies at regional, national and international levels.

Introduction

There is a history in Inuvialuit communities of miscommunication regarding contaminant issues, and such instances have led to unnecessary alarm, apprehension and mistrust. Language and cultural barriers have been major obstacles to effective communication. Promising communications strategies have now been developed at the community level and there has been increased communication at the regional and inter-regional levels.

Communication of contaminants information and data from technical components of the NCP is a major element of Phase II of the NCP. Inuvialuit who consume large amounts of traditional/country foods are continually requesting information on the levels of contaminants present in their area and their potential impact on people and the environment. Many of these requests have led to workshops dedicated to contaminants information, which are able to summarize and communicate information from past and present contaminants-related research, such as the Centre for Indigenous Peoples' Nutrition and Environment (CINE) dietary benefits/risks study (Kuhnlein et al. 2000), the Inuvik Regional Human Contaminants Monitoring Program (Tofflemire 2000) and the status of contaminants in fish and marine mammals in the ISR (Macdonald 2000).

Inuvialuit are concerned about contaminated sites from past Distant Early Warning (DEW) Line sites and abandoned oil exploration sites, where past and present activities have left contaminants behind. Efforts have been made to deal with these concerns, such as the Department of National Defence's DEW Line clean-up projects; in addition, abandoned well sites are still an issue. The current priority of the Inuvialuit RCC is to work with the different levels of government, various communities and industry to begin updating information on contaminated sites in the ISR and to assess specific sites about which communities are concerned.

Reports on two major nutritional surveys were made available in 2000 (Kuhnlein et al. 2000, Usher 2001) and it is vital that this information be communicated throughout the ISR in an effective and culturally appropriate manner. There is also a need for broad community dissemination of information on sensitive and current issues, such as mercury levels in beluga muktuk, the clean-up of abandoned DEW Line sites, the increasing awareness of abnormalities in fish and wildlife, high cancer rates and safety of community drinking water.

Informal discussions with researchers have taken place to consider the establishment of a comprehensive monitoring program for the ISR, which would include a schedule for the analysis of contaminants in various fish and wildlife species. The expertise from the scientific community is needed to determine when to analyze for various contaminants and to help determine any trends in contaminant concentrations in species harvested by Inuvialuit.

Activities in 2000-2001

The RCC position was filled by Billy Archie in July 2000. Activities included:

- Ongoing communications took place in all ISR communities through memos and quarterly reports drafted by the RCC.
- Public meetings on contaminants with community corporations, hunters and trappers committees, and local high schools were held during an all-community tour, which took place in January 2001.
- A contaminants awareness poster was developed and distributed to all ISR communities; two additional posters were drafted during the CINE Dietary Results workshop, held April 4-5, 2001.
- Working relationships were established with research institutions, government departments/agencies, and Inuvialuit co-management boards.
- Discussions took place with various agencies to work toward developing a comprehensive contaminants monitoring program by 2003.
- Participation at one regional and three national contaminant workshops, and six Northwest Territories Environmental Contaminants Committee meetings.
- Informal discussions took place with researchers to consider the establishment of a comprehensive monitoring program for contaminants in various fish and wildlife species in the ISR. The expertise from the scientific community is needed to determine when to analyze for various contaminants and to help determine whether contaminants are increasing or decreasing in all species harvested by Inuvialuit.

A contaminants report is now a standard agenda item at all meetings of the IRC and at Inuvialuit Game Council quarterly meetings.

Results and Discussion

The RCC has been acting as a conduit for a two-way information exchange between communities and the NCP, and has brought contaminants issues to the attention of various individuals and agencies. A few proposals were drafted and submitted by the RCC, and some funding has been approved for these proposed projects as well as studies by other researchers conducting work in the ISR.

From NCP related projects conducted in the ISR, such as dietary studies, Inuvialuit have been informed that contaminants are present in traditional/country foods but at low levels, and thus monitoring should continue. A specific priority should be to monitor heavy metals (methylmercury) in marine mammals.

Health-related comments and concerns were expressed by Inuvialuit communities during the Inuvialuit Community Tour, which took place in January 2001. In general, all communities had questions about contaminants, global warming and the oil and gas industry/development. Specific concerns of the communities are listed below.

Tuktoyaktuk

- The ocean is flooding the dump/land fill each year – What about contaminants getting into the fish?
- Questions about various parasites found in traditional/country foods, specifically brucellosis and botulism – Are doctors and nurses in the North trained to recognize symptoms?
- One woman had her hair sampled years ago by Health Canada for mercury levels and her daughter had been involved in the maternal cord blood study – She was glad to see that monitoring was continuing over the years.
- Contaminant levels in geese and birds – There is no information on geese gizzards which are an important food source.

Paulatuk

- Brucellosis in caribou.
- Global warming and changes in caribou herd migration.
- Contaminant levels in migratory birds.

Holman

- Residents do not drink tap water, they drink water from melted ice blocks – Can that water be tested?
- Parasites and bacteria in food, including brucellosis.
- Contaminants in king eiders and geese.
- Information on contaminants and traditional/country foods for prenatal nutrition and a copy of the NWT nutrition fact sheets.

Sachs Harbour

- Contaminant levels in geese and migratory birds.
- Climate change.

Inuvik

- Oil and gas development.
- Dumps – regulating what is being dumped.
- Relative risk.

- *Helicobacter pylori* in the drinking water.
- Making sure communication occurs with residents before the press.

Aklavik

- Exposure to asbestos – It was removed from the school and placed in the dump.
- H. *pylori* and cancer – Where can they find funding for a study?
- Contaminants from DEW line sites.
- Oil and gas industry.
- Steroids and hormones added to meat products.
- Dump and sewage lagoon.
- More information on levels of concern and acceptable daily intakes for contaminants in food.

Action items as a result of the tour

- Send more copies of the cigarette poster to schools that requested them.
- Send Nutrition Fact Sheet Series to those who requested them.
- Develop presentation slides illustrating studies and health effects associated with mercury, cadmium, lead, organochlorines, PCBs, ADIs and acceptable weekly intakes for traditional/country foods.
- Develop proposals to begin addressing concerns raised by the communities.
- Continue to develop information for the schools, by providing more material and resources.
- Begin working with the Fisheries Joint Management Committee Summer Student Mentorship Program.

Conclusions

The role of the RCC in the ISR is to bridge the gap between community members and NCP scientists and management. Local concerns focus on local sources of contamination, but this does not fall within the NCP mandate. To build trust and respect, it is important to be able to address some of these non-NCP concerns. The RCC felt that in order to communicate NCP information, he must first be aware of the big picture in his region, in particular, knowing who is responsible for specific local issues of water or waste management and what is being done about them. Therefore, in order to be effective, RCCs must be aware of issues both within and outside the NCP mandate.

This year, the ISR submitted a few proposals to the NCP demonstrating the education and effective capacity building that is occurring in this region. Some of these proposals were approved and contaminant research in the ISR is slowly taking on a local flair that reflects the concerns of the people and communities.

One important thing that was learned from work conducted in the ISR in 2000- 2001 was the results of work conducted by CINE, which was brought to the attention of the ISR. Examining the dietary study, as was done in the late winter, showed that for the most part, the people in the ISR are exposed to relatively low levels of contaminants. This being the case, the RCC urges the NCP to keep up their monitoring efforts, especially for marine mammals and species which are at risk for heavy metals, particularly methylmercury.

Expected Project Completion Date

This project is ongoing.

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Incorporation of Scientific Knowledge into Inuit Knowledge in Nunavik

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Abstract

The problem of food chain contamination creates a complex situation affecting the heart of the culture and traditions of the Inuit population, particularly in relation to nutrition and health. From the health expert's viewpoint, food is understood and treated as both a risk and a protective factor for health and well-being. Consequently, the content of the message disseminated to the Inuit population is often ambivalent and confusing because it focuses concomitantly on potential risks related to chronic exposure to contaminants as well as positive health aspects of a diet based on fish and marine mammals. Therefore, it is important to question the relationship between expert and Inuit knowledge, more specifically in the way they incorporate one another. Using the case of information related to contaminants in traditional/country food, this study will gain a better understanding of the strategies used by a social group, to adapt to this problem in their daily lives. Furthermore, it will help to better understand how, and in what form, to better develop and deliver the messages on these issues in health education and promotion programs in the North.

Key Project Messages

1. The present study will provide information for the Inuit population and environmental health communicators to help better orient their communication activities related to health and contaminants issues.
2. The results are anticipated to provide evidence as to why and how communication activities organized and delivered by health experts and researchers still create some misunderstanding and confusion among the public

Objectives

1. Describe the content and organization of the social representations of the ideas of nutrition and health in the Inuit population in order to identify their common organizing principles (central core).

2. Examine the operation of these social representations by studying their link with daily nutrition and health practices. In a context of food chain contamination that has prevailed for more than 10 years in Nunavik, it seems pertinent to examine whether this situation has created an imbalance in understanding strong enough for subjects to begin adopting practices related to nutrition and health that are contradictory with what is usually considered habitual.
3. Support future common activities on these issues by giving a better understanding of the comprehension and impact of this information in Inuit communities.

Introduction

The scientific uncertainty surrounding the effects of chronic exposure to food chain contaminants is a reality. The objectives of many epidemiological studies done in the Arctic is to quantify the health effects linked with a diet rich in sea products. Many of these same studies have shown that a diet rich in sea products is also rich in nutrients such as omega-3 fatty acids and selenium (Nettleton 1993, Olsen et al. 1990). However, there has been no clear demonstration of the presence of real risks associated with the levels of exposure to contaminants experienced.

In this context, it is not surprising that the message disseminated to the population has often been ambivalent and confusing. On one hand, the information on the potential risks linked to chronic contaminants exposure is disseminated and, on the other, public health authorities promote through video, pamphlet, radio and TV program, a diet based on marine products because of the real benefits associated with their consumption.

Contamination of wildlife by toxic substances is a foreign concept to the Inuit understanding of animal health because the risk is imposed by something that is invisible and without odour. This invisible link has created certain confusion (Usher et al. 1992). In spite of the major changes that have occurred in Nunavik in the last decades, the Inuit population has stayed very close to their traditions. Traditional knowledge is still prevalent and reveals how important the sharing relationship is between Inuit and their environment (Freeman 1992). Attached to these activities are not only social and cultural values but also an essential link with individual and collective well-being.

By studying the integration of scientific knowledge into Inuit knowledge, data will be collected in this study to understand how this information on potential risks and real benefits associated with consumption of a traditional diet is incorporated, understood, expressed and linked with Inuit knowledge on these issues – particularly with respect to food and health dimensions. Often called lay or common knowledge, sometimes popular or naive, this base of knowledge is worthy of serious attention. For Massé (1995), popular knowledge related to health and disease integrates valid scientific information as well as beliefs, attitudes, values, conceptions or popular representations. In the image of popular culture, it is an original product that resulting from a global reinterpretation of various discourses (medical, alternative, popular) on health.

The chosen theoretical framework upon which to base the proposed study is the theory of social representations. Social representations are like ideas and images that comes to people's minds when they try to understand different kinds of information. These ideas and images are influenced by past experiences and help people to gain control over a wide range of problems and situations they face in their daily lives (e.g. news of food chain contamination) (Jodelet, 1989, Moscovici, 1961). Therefore, the main objective here is not to learn what one Inuk is thinking but rather to have access to social entities that are built by the group to which the individual belongs (e.g. a northern community).

Among reasons that explain the choice of the theory of social representation and the associated research methods to investigate the proposed subject in northern communities are:

- the importance of the "community" as a collective group in Inuit society (Dufour 1995, Therrien 1987),
- the role that traditional/country foods play in supporting an individual's ability to participate and be an active member in his/her her community (Boré 1994), and
- the importance of studying the impacts of communication efforts on how people act in relation to these issues. Transfer of information from the experts to the population may affect certain social practices.

Activities in 2000-2001

A first visit to Salluit was organized in November 2000. At that time, the Municipal Council and the Local Health Committee gave strong support for this project. The mayor and a member of the Local Health Committee participated in an FM radio show to encourage the Salluit residents to take part in this project if contacted. Since early 2001, the project, as originally proposed, has been modified in order to better meet the interests of Salluit partners and of the Northern Contaminants Program Management Committee (e.g. clarification of methods used and their strength in illuminating the various aspects of the issue has been done for the community and review committee; participants to be involved have considered the community's recommendations; and methods to present results have been discussed with the Nunavik Nutrition and Health Committee and the community, and will be used for dissemination of the results). Particular efforts have been made to make the project easier for everyone involved to understand. This project has been reallocated for year 2001-2002.

Discussion and Conclusions

This study will provide a better understanding of strategies developed by the residents of Nunavik, as members of a social group, when adapting to this "new" context created by the discovery, more than a decade ago, of food chain contamination. More importantly, it is anticipated that results will provide evidence as to why and how communication activities, as they are currently organized by public health experts and researchers, still create misunderstandings among the public because of a potential lack of consideration of some aspects related to the daily reality of the population dealing with the problem. Thus, the present study will provide information for the Inuit population and environmental health communicators to help better orient their communication activities related to these issues.

In June 2001, the principal researcher went to Kuujjuaq to collect oral and written material (health advisories, meeting minutes, video content, radio and television shows, etc.) dealing with the topics of contaminants, traditional/country food and health. Documents to be reviewed consist of: 1) scientific material which is generally prepared by experts and given to local authorities in a form of a final report, etc; 2) synthesized or vulgarized information (simplified summaries of final project reports focussing on study highlights and promotional messages [video, message on radio or TV] encouraging the population to continue eating traditional/country food). Document review will allow the identification of the expert discourse (key words and phrases) on food chain contamination, how this information is disseminated to the general population and why (if it does) it takes the form of an ambivalent health promotion message. Some documents may also help identify strategies adopted by the population to deal with the problem and with the ambiguity of the messages.

In the fall of 2001, semi-directed interviews will be performed with Salluit residents. The objective of this stage of work is to uncover the collective discourse of Nunavik residents on food and health and to pinpoint the organizing principles of these social representations.

Expected Project Completion Date

This project is ongoing and the completion date is expected for April 2002.

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Gwich'in Tribal Council Regional Contaminants Coordinator

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Abstract

The Gwich'in consume traditional/country foods as a main staple of their diet. Due to concerns from the Gwich'in in regards to contaminants in the food chain, the Regional Contaminants Coordinator (RCC) position was established. This position enabled the Gwich'in to be a member of and participate in research programs established by the Northern Contaminants Program (NCP). During 2000-2001, the second year that the Gwich'in were involved with the NCP, the RCC held workshops, attended meetings/workshops, developed proposals, established research programs and distributed relevant information to the Gwich'in communities. Furthermore, the RCC participated in other non-NCP environmental programs in a technical capacity. Finally, the RCC attended NCP activities, which included the annual Results Workshop, Human Health Workshop, Country Food Monitoring Workshop, Wildlife Disease Training, and participated as a member of the Northwest Territories Environmental Contaminants Committee.

Key Project Messages

1. The Gwich'in Regional Contaminants Coordinator (RCC) has raised the awareness of the Gwich'in in regards to local, national and international contaminant issues. He held workshops, attended meetings/workshops, developed proposals, established research programs and distributed relevant information to the Gwich'in communities.
2. Gwich'in continue to harvest and consume traditional/country foods.
3. The RCC has attended several workshops to enhance his capacity to carry out the duties of his position.

Objectives

1. Promote the Gwich'in Tribal Council as a partner in the Northern Contaminants Program (NCP) by attending Northwest Territories Environmental Contaminants Committee (NWTECC) meetings and participating in research programs funded by the NCP.
2. Assist Gwich'in communities to identify and develop research programs.
3. Inform and educate the public about contaminants within the Gwich'in Settlement Area.
4. Present the results from studies that are relevant to the communities in the Gwich'in Settlement Area.

5. Increase capacity at the regional/local level.
6. Coordinate regional studies.
7. Identify complementary environmental issues and funding sources.

Introduction

The RCC position is an integral part of the NCP. These front line workers are a key component in terms of the communications aspect of the NCP. The Gwich'in still have strong ties to the land and major components of those ties are the harvesting and consumption of traditional foods. Recently, the Gwich'in have been very concerned about long-range and local source contaminants getting into the food chain. They want to know the levels of contaminants in the traditional/country foods and the possible effects of consuming these foods. Through the NCP, whose mandate is to address these issues and concerns through research and related activities, the Gwich'in Tribal Council established an RCC position. In conjunction with scientists, the RCC established research programs to address the concerns of the Gwich'in. The RCC also communicated Gwich'in concerns to the NCP.

Activities in 2000-2001

This has been the second year that the Gwich'in have participated in the NCP. This year the RCC, Norman Snowshoe, completed the project, 1999 Peel River Fish Contaminant Study, which involved the collection and analysis of 30 fish from Fort McPherson, NWT. A second project, which involves the collection of 30 fish from Tsiigehtchic, NWT has been started.

This year the Gwich'in RCC submitted three proposals for funding from the NCP. These included, Uptake of Contaminants in Beaver and Muskrat of the Mackenzie River Delta, Regional Contaminants Coordinator, and Regional Health Workshop.

Information on contaminants issues has continued to be sent out the communities by the RCC.

This year, the RCC attended the NCP annual Results Workshop, Contaminants and Human Health in the Canadian Arctic: An Update, Country Food Monitoring Workshop, NWTECC proposal review and NWTECC meetings.

The RCC has also been involved with non-NCP related environmental programs in an advisory capacity on behalf of the Gwich'in Tribal Council. These programs include Yukon Development Assessment Process, Cumulative Effects Assessment, Fort McPherson Deep Water Lake Project, Peel-Caribou River Remediation Project, Climate Change Exchange and NWT *Wildlife Act* amendments.

Results

The RCC has raised the awareness of the Gwich'in in regards to local, national and international contaminant issues. The report, 1999 Peel River Fish Contaminant Study, was produced in conjunction with the Department of Fisheries and Oceans. Two projects have been funded by NCP for the year 2001-2002. These projects are Tsiigehtchic Fish Study and Beaver and Muskrat Uptake of Contaminants in the Mackenzie Delta. Funding for the RCC position for the year 2001-2002 has also been secured. Major developments occurred this year on the local source issue Peel-Caribou River Remediation Project; the Gwich'in Tribal Council received commitments from the Department of Indian Affairs and Northern Development and Shell Oil to begin clean-up of the site.

Discussion and Conclusions

During the past year the RCC has been very involved in addressing contaminants-related issues. The Gwich'in continue to harvest and consume traditional/country foods. There is still a lot of concern about whether the food is safe to eat as a result of worldwide emissions of pollutants. The RCC has addressed most concerns of the residents of the Gwich'in Settlement Area by gathering, organizing and distributing information, and initiating research programs. The RCC has attended several workshops to enhance his capacity to carry out the duties of his position. Furthermore, based on the requirements of information by the residents of the Gwich'in Settlement Area, it has been demonstrated that this position is an integral part of the NCP.

Expected Project Completion Date

The RCC position in the Gwich'in Settlement Area has been renewed for 2001-2002 and thus work of the RCC is ongoing.

Communication Through Fabric Art – *Bear Coming Undone*

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Abstract

The aim of this project was to produce a fabric wall hanging that represents the contaminant issue as it affects the Arctic marine food chain that supports polar bears. It is hoped that this work will promote dialogue of the contaminant issues particularly in cross-cultural situations. Experience has shown that non-verbal messages are often the key to starting meaningful discussions. This quilt will travel to community meetings, national and international meetings, and Northern Contaminants Program workshops and events.

Key Project Messages

1. Contaminants are a global issue that can only be resolved with international cooperation.
2. The effects of contaminants in the North are not always immediately apparent, they are often insidious and need closer inspection.

Objectives

1. Provide a vehicle for discussion of the issues of contamination of the marine mammal food chain.
2. Provide a catalyst for discussion that will lead to informed decision-making on the issue of safety and nutritional benefits of traditional/country foods.
3. Produce a quilted fabric wall hanging to be used by the Northern Contaminants Program at community, national and international functions to promote the objectives of the program.

Introduction

There is a need to communicate important messages regarding contaminants to northern Aboriginal people without being alarmist. Experience has shown that two key elements to meaningful cross-cultural communication are trust and sharing. Time is also a consideration. Communication cannot be rushed. For generations, northern Aboriginal people relied on keen observation for survival. Those observation skills manifest themselves today in the execution of northern art. Print making, carving, sewing, fashion design, tapestry weaving and beading are some of the art forms that have been embraced by Northerners over the years to a point where they have developed their own style. Northerners appreciate the time taken to work materials into a visual interpretation of their environment. They respect the time and effort because there are many aspects of their daily lives that require such effort. This respect can be a very powerful tool.

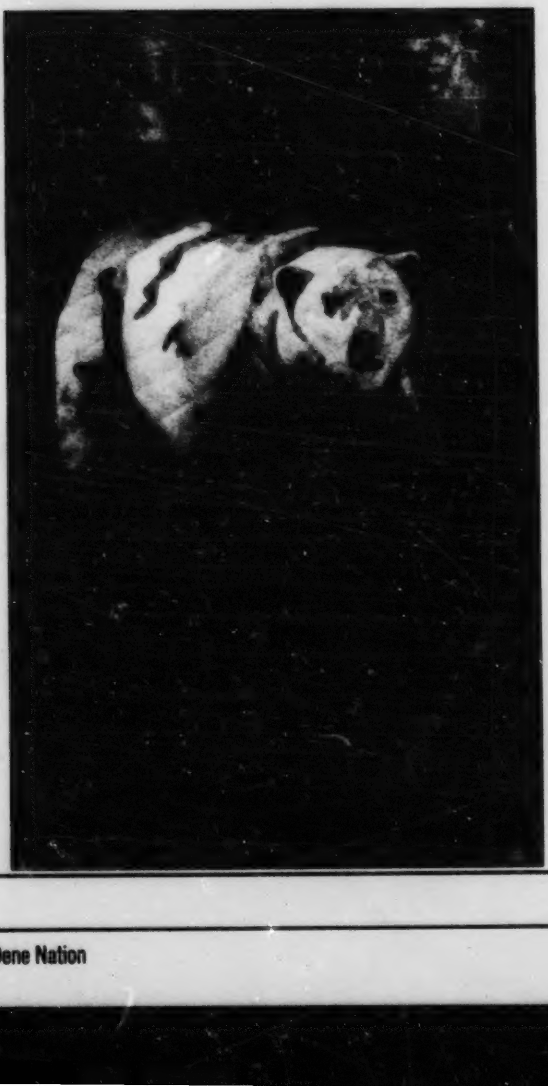
The bear is a powerful symbol with which people can readily identify. The concept of a "bear coming undone" can be taken literally and figuratively. All people can embrace the symbol of the polar bear but it is particularly appropriate to Inuit, Inuvialuit who live on the coast, and Gwich'in who travel to the coast to hunt.

It is hoped that this project will lead to capacity building through the promotion of community based projects, in schools or friendship centres. Active participation promotes long lasting learning. People will be encouraged to touch and feel the quilt and explore it for hidden messages. It is interactive art.

Activities in 2000-2001

The design concept was developed and the wall hanging was constructed. The materials used include hand dyed cotton fabric. Text from the *Canadian Arctic Contaminants Assessment Report* (CACAR) (Jensen et al. 1997) dealing with polar bears was reproduced on the fabric and used to create parts of the bear. A travel schedule is in preparation for 2001-2002. An artist statement, a book for viewers to record written comments and a tape recorder for those who prefer to give oral comments, will accompany the quilt.

Figure 1. ***Bear Coming Undone*** **quilted fabric collage**



Results

The wall hanging was completed in March 2001 but has not yet been used at meetings, workshops or other events.

Discussion and Conclusions

The quilt features a great white bear surrounded by graphic images representing industrial and agricultural practices, radionuclides, persistent organic pollutants and heavy metals (Figure 1). This is not the scene that is normally associated with polar bears. The viewer becomes aware of a world map because this is a global issue. Closer inspection reveals the bear to be coming apart; his chest opens to reveal text from the section dealing with polar bears from CACAR (Figure 2). Even parts of the body and head are made up of text from the report (Figure 3), but it doesn't make sense. It doesn't make sense because we can't see all of it and it is taken out of context, which is precisely the point. Scientific reports are often so far removed from the reality or context of northern life that they are not culturally appropriate. Art that allows individual interpretations will promote discussion and can be used, with the skills of a facilitator, to lead discussion to the relevant issues.

Pockets on the back of the quilt contain shapes representing the organisms that make up the long marine mammal food chain. These are for use during discussion of contaminant issues of the Arctic marine food chains.

Figure 2. Detail of ***Bear Coming Undone***

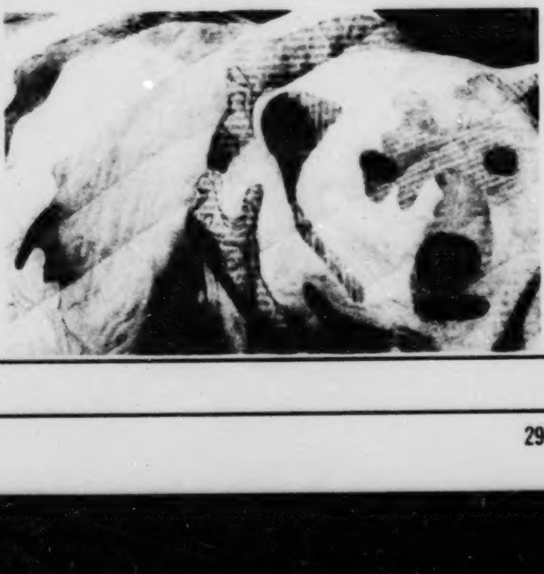
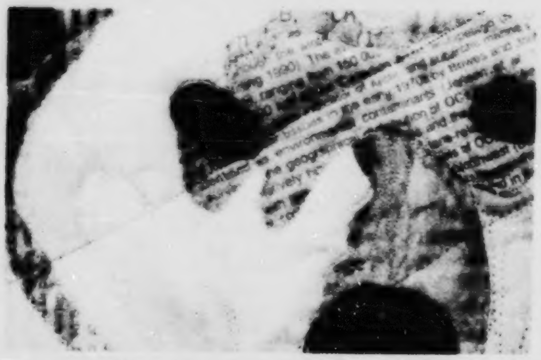


Figure 3. Detail of *Bear Coming Undone* showing text from the Canadian Arctic Contaminants Assessment Report



Project Completion Date

March 31, 2001

Evaluating Contaminants Curriculum Materials

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Abstract

This project evaluates and contrasts the contaminants-related curriculum materials that have been produced in the Northwest Territories, Nunavut and Yukon, using a teacher survey and key informant interviews. Recommendations were compiled through key informant interviews. Current materials were evaluated as being quite useful, and almost all teachers felt that contaminants issues should be included in the science curriculum. It was determined that the production of curriculum materials is more cost effective when coordinated directly through a territorial contaminants committee, as opposed to funding an intermediate organization. The study also determined that supplementary resources are needed to complement lesson plans, more in-service training would be valuable for teachers of earlier grades, and materials may need occasional re-drafting to ensure their compatibility with school curricula.

Key Project Messages

1. Effective contaminants materials for schools should begin in early grades, with materials that fit easily into the existing curricula.
2. Hands-on activities and supplementary resources are desirable complements to contaminants teaching packages.
3. Occasional re-circulation of educational materials would help to ensure that teachers are aware of these resources.

Objectives

1. Evaluate teachers' awareness and use of existing contaminants-related educational material.
2. Collect teachers' impressions of existing materials.
3. Identify issues associated with development of materials and assess relative costs.

Introduction

In January 2001, the Contaminants Division of the Department of Indian Affairs and Northern Development (DIAND) contracted the Dene Cultural Institute (DCI) to evaluate the introduction, acceptance and continued implementation of the *Contaminants in Northern Canada* curriculum materials, developed by the Métis Nation-

Northwest Territories (NWT). These materials were developed between 1993 and 1999, and distributed to all of the junior and senior high schools in what are now the NWT and Nunavut.

The Contaminants Division also wanted a preliminary comparison of the approach taken in the development of the NWT/Nunavut materials – including the cost of producing the materials – with the approach taken by the Yukon Contaminants Committee in its development of a similar contaminants curriculum entitled *Contaminants Found Me*. The Yukon materials were produced and distributed between 1998 and 2000.

Activities in 2000-2001

To evaluate the *Contaminants in Northern Canada* curriculum materials, the following steps were taken:

- A preliminary teleconference call was held to identify and clarify key information required from the questionnaire.
- A series of draft questionnaires were formatively reviewed by DCI and DIAND personnel.

Based on this review process, a final questionnaire was drafted. This questionnaire targeted junior and senior level science teachers. DCI staff faxed copies of the questionnaire, with a covering letter, to 70 schools in the NWT and Nunavut, based on a list provided by the Contaminants Division. Due to a low initial response, DCI staff phoned all of the schools that had not responded and encouraged them to complete the questionnaire. Questionnaires were re-faxed to some schools.

A number of the schools did not complete the questionnaire because they did not have junior or senior students, only elementary students. In all, 25 questionnaires from 22 schools (Table 1) were completed and returned by science teachers, representing an approximate return rate of 40% when elementary schools were excluded; responses were evenly split between the NWT and Nunavut.

During the time that the questionnaires were being distributed, the following expert authorities were interviewed:

- Judy Farrow, the consultant who researched and drafted the *Contaminants in Northern Canada* curriculum materials for the Métis Nation-Northwest Territoires;
- Bill Carpenter, Environmental Director of the Métis Nation-Northwest Territoires, who coordinated the curriculum project;
- Pat Roach, a DIAND official who currently chairs the Yukon Contaminants Committee; and
- Jeannie Burke, the Yukon consultant who researched and drafted the *Contaminants Found Me* curriculum materials.

Table 1: Northwest Territories and Nunavut schools that participated in the contaminants curriculum materials evaluation

School	Community
Alaittuq High School	Rankin Inlet, NU
Ataguttaaluk High School	Igloolik, NU
Charles Tetcho School	Trout Lake, NT
Charles Yohin School	Nahanni Butte, NT
Chief Paul Niditchie School	Tsiigehtchic, NT
Ecole Allain St-Cyr	Yellowknife, NT
Ecole St. Joseph School	Yellowknife, NT
Ehtseo Ayha School	Deline, NT
Inuglak School	Whale Cove, NU
Inuksuk School	Iqaluit, NU
Inuujaq School	Arctic Bay, NU
Jean Wetrade Gameti School	Rae Lakes, NT
Jimmy Hikok Ilihakvik School	Kugluktuk, NT
Jonah Amitnaaq School	Baker Lake, NU
Kakisa Lake School	Kakisa Lake, NT
Killinik High School	Cambridge Bay, NU
Kugaardjuq School	Pelly Bay, NU
Netsilik School	Taloyoak, NU
Qaqqalik School	Kimmirut, NU
Range Lake North School	Yellowknife, NT
Samuel Hearne Secondary School	Inuvik, NT
Thomas Simpson High School	Fort Simpson, NT

All of the data from the completed questionnaires were entered into a simple database, correlated and then entered into a master questionnaire. This information was then analyzed, along with information from the personal interviews, and the final report was prepared.

Results

Twenty-four of the 25 respondents felt that was it important or very important to teach about northern contaminants as a component of the science curriculum. They believed that the issue of contaminants is of immediate importance to students' lives, given that many northerners still live off the land. Eighteen of the respondents presently teach lessons about northern ontaminants, using a variety of materials including the *Contaminants in Northern Canada* materials.

It is clear from these responses that teachers are eager to access lessons and materials on northern contaminants and integrate them into their respective science curriculums.

Of the 25 respondents, 14 were aware of and have used the *Contaminants in Northern Canada* curriculum materials. These teachers became aware of the materials either when they were first distributed to the schools, through other science teachers, through in-servicing workshops, or by finding them on the shelves in their science and resource rooms. In effect, the materials, once distributed, have been circulated, maintained and used in most schools. However, 11 of the respondents were not aware of the materials, so some schools have either misplaced the materials or the materials were not actively promoted within the school or school district. All of these respondents were interested in getting copies of the materials. These results indicate that ongoing distribution and promotion of the existing materials would be of great benefit to northern science teachers. It also appears that the junior high materials are used most often.

A large majority of those respondents who had previously reviewed or used the materials indicated that the materials were compatible with the existing science curriculum and that the content and structure of the lesson plans was very good. Most of the respondents also indicated that students responded well to the topics and materials. A smaller majority approved of the layout and graphics of the texts. Most of the respondents indicated that more supplementary resources were required to enhance the teaching of the materials. Some of the teachers also noted that the reading level was a bit high for ESL (English as a second language) students, particularly in Nunavut.

The responses indicate that the existing curriculum materials (particularly the junior high materials) can continue to be used as they are, but that attention should be paid to the development of supplementary materials and resources. Such supplementary materials should incorporate more graphics, hands-on activities, and plain language text.

Discussion and Conclusions

When asked to rate the usefulness of a few possible key actions that could be taken to enhance the use of the contaminants curriculum materials in northern schools, the following priorities emerged.

***Highest priority*:** Develop and circulate more resources to complement the lesson plans.

***Second priorities*:** Re-draft the materials to make them more compatible with the existing curriculum; and, provide in-service training to teachers regarding implementation of the lesson plans.

***Third priority*:** Re-publish and re-distribute the materials.

***Lower priority*:** Provide materials in digital/electronic format.

Other suggestions included providing video materials, providing access to contaminant experts through the Internet, developing materials that link the impact of contaminants to a northern Aboriginal lifestyle, and providing current information about contaminant monitoring, prevention and reduction.

The main comments and recommendations that emerged from key interviews were as follows:

- Supplementary curriculum materials, such as the *Contaminants in Northern Canada* materials, must be directly applicable to the existing curriculum and must be easy to utilize by teachers and students.
- Promotion of these materials must be ongoing, through redistribution and regular in-service training of teachers in each of the regions.
- It is appropriate to develop contaminants materials for the elementary grades. In fact, it is often easier for teachers at the elementary level to integrate these kinds of supplementary curriculum materials because the basic curriculum is more flexible. Also, it is easier to affect changes in students attitudes toward the environment at an elementary school age. It is harder to integrate these types of materials into the senior high school curriculum.
- The materials would tend to be used more if additional resource materials and resource kits were available, particularly hands-on type resources.
- The strong focus on marine mammals in the NWT/Nunavut materials is not necessarily appropriate for the Yukon or southern NWT.

The following general conclusions were reached:

1. It would be worthwhile to reprint and re-circulate copies of the grades 7 and 8 lesson plans, the grades 7 and 8 teacher guide, and the manual for science teachers for grades 10 and 11.
2. If further funding were available, the following actions could be taken, in order of priority.
    - In-service training could be provided to grades 7 and 8 science teachers in the NWT and Nunavut regarding the use of the existing contaminants materials and awareness of contaminants issues

in general. This training could be coupled with regional or territorial teacher conferences or other types of gatherings.

- Supplementary resource materials and resource kits could be prepared for the grade 7 and 8 lesson plans. These resources would have to reflect different land use patterns and lifestyles between the NWT and Nunavut. They would use graphics, identify hands-on activities, use plain language text, and incorporate Aboriginal cultural approaches to environmental protection, including Aboriginal languages and traditional knowledge. A multi-media CD-ROM format might be considered as a key component of these resource materials, with Internet links to organizations that deal with contaminant issues.
- Northern contaminant lesson plans and resources could be developed for grades 4 to 6 and circulated throughout the NWT and Nunavut. This age group is an excellent target group for this type of information.

3. The development of new resource and curriculum materials must be done more cost-effectively. A Request for Proposals with clear terms of reference would be the most appropriate way to contract out specific projects. A multi-agency steering committee, chaired by the Contaminants Division, DIAND, could provide project guidance.

Project Completion Date

March 31, 2001

Council of Yukon First Nations – Contaminants Web Site

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Abstract

A Council of Yukon First Nations (CYFN) contaminants Web site was created to communicate information from the CYFN and the Northern Contaminants Program (NCP). The Web site (www.contaminants.ca) is to be used as an educational tool and will communicate information previously generated by the NCP, the Yukon Contaminants Committee, and the Centre for Indigenous Peoples' Nutrition and Environment. It was created with children as the target audience. However, it will also be able to serve the more demanding needs of researchers requiring specific information about the NCP. The site is comprised of four main sections (About Contaminants, What We're Doing, What We've Done, Submit Your Proposal). These provide communities with information on what the NCP is about, what contaminants are, where they come from, their potential effects on human health and wildlife, reports that have been produced by the NCP, and how to submit proposals for possible studies in the future. Further additions will be made as the work is continued.

Key Project Messages

1. Contaminant information can be easily accessed by community members through the Council of Yukon First Nations (CYFN) contaminants Web site.
2. The contents of the Web site were generated from information from the Northern Contaminants Program (NCP) and the Yukon Contaminants Committee (YCC).
3. The Web site is broken down into four main sections: About Contaminants, What We're Doing, What We've Done, and Submit Your Proposal.
4. The address is www.contaminants.ca.

Objective

- The objective of the CYFN contaminants Web site is to communicate information generated by the CYFN and the NCP. It will be used as an educational tool that can be easily accessed by community members, health professionals, organizations, instructors and those interested in learning about the effects of long-range contaminants in the North.

Introduction

Through the NCP, a large body of information on contaminants and traditional diets has been generated. The CYFN and Centre for Indigenous Peoples' Nutrition and Environment have conducted research and held many workshops on traditional/country foods in the Yukon. As well, the YCC has a database containing results of studies on fish, birds, mammals and vegetation from across the Yukon that have been analyzed for organochlorine compounds and metals. The information from these workshops and the research results should be communicated to communities. With more Yukon communities currently enjoying Internet access, accessibility to information has improved. Because of this increased access, the creation of a Web site that would communicate information from workshops and research, and be updated periodically, would be beneficial to communities.

The CYFN contaminants Web site is intended for community use, to gain a better understanding of what the NCP is about, what contaminants are, where they come from, and their potential effects on human health and wildlife. It is designed to serve three primary purposes:

- Reduce the costs of distributing information.
- Simplify access to information.
- Increase the range of information provided to Northerners.

Activities in 2000-2001

The development of the Web site involved gathering, digitizing and formatting a large body of contaminant information currently available from the NCP and YCC. This information was organized in an easy-to-navigate site. Text material was made searchable, diagrams, illustrations and photographs were digitized, and a video produced by the YCC was digitized for on-line viewing. The focus was to create a site that could communicate information in an engaging and visually pleasing manner.

The Web site is broken down into four main sections:

- About Contaminants
- What We're Doing
- What We've Done
- Submit Your Proposal

The Web site, www.contaminants.ca, was launched in April 2001.

Discussion and Conclusions

The Web site was developed with a target audience of children in mind; therefore, access to information has been simplified and the visual qualities are colourful and simple. The site is, however, articulate enough to serve the more demanding needs of the researcher requiring specific information about the NCP.

Its location was established at the following easy-to-remember URL: http://www.contaminants.ca and the domain name "contaminants.ca" was registered to the NCP at CYFN. It is under the direct control of CYFN.

The "About Contaminants" section of the Web site is essentially an online adaptation of the *Contaminants Found Me* curriculum, developed with the cooperation of the Yukon Department of Education, the Yukon Contaminants Committee, scientists working in the field of contaminants, and Yukon teachers and students. The curriculum was converted to a digital format (Portable Document Format [PDF]), which is readable by a free and widely accessible software package (Adobe Acrobat Reader). The curriculum content was re-worked to better suit on-line delivery, with a fully hyper-linked and non-linear based navigational interface and additional elements that make the subject matter easier to explore and understand. The full curriculum documents can be downloaded and viewed or printed by visitors exactly as the documents were originally laid out and printed. This will make it easy for users of the curriculum to produce and distribute additional copies of the document as needed.

The "What We're Doing" section describes the NCP, and the activities in which it is involved. This section can be managed and updated by staff at the CYFN office, as required. This section outlines various reports, studies and other materials that the NCP has produced in the past. Some of these materials were digitized specifically for this Web site and are available on-line. Included in this section are the following:

- Traditional Knowledge Research Guidelines (PDF and HTML formats)
- Yukon First Nations Assessment Dietary Benefit/Risk (PDF and HTML)
- Front Line Training Report (Microsoft Word)
- Air, Water, Fire, Earth and Youth Report (Microsoft Word)
- Dietary Benefits and Risk Conference Report (Microsoft Word)
- *Contaminants Found Me* video (QuickTime)
- *Contaminants Found Me* music CD (QuickTime and MP3)

- *Contaminants Found Me* curriculum (links to the "About Contaminants" Web site section)

The "Submit Your Proposal" section provides full details and information on submitting proposals to the NCP.

The Web site is easy to navigate and all of the main reports on it can be downloaded in either PDF or Word format. Contact information is also available. Future additions will be made as CYFN continues work on northern contaminants.

Project Completion Date

The initial development of the Web site was completed in April 2001. It will continue to be updated and maintained by the CYFN.

Frontline Training for Professionals in the Yukon

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Abstract

Due to the difficulties faced in communicating contaminant information to communities, a Frontline Training Course was developed to train community representatives so that they could help in communicating this information. The course provided background information on contaminants, the Northern Contaminants Program and previously conducted dietary studies, and allowed for discussions on specific contaminants and recommended intake levels. From these discussions, participants learned that current cadmium intakes through the consumption of traditional/country food do not exceed the recommended intake levels and are lower than the intake levels for smoking. Course surveys were distributed to the participants pre- and post-training to gain a better understanding of what they knew before the course, what they had learned by having taken the course and to receive feedback. Participants stated that the course was successful. Recommendations for future workshops included involving Yukon College – Professional Studies, youth and more people who work in the lands and resource area. Participants stated that their main concern related to health and the environment, such as contaminants in traditional/country foods, cancer, high rates of diabetes, garbage and recycling, monitoring health, how to encourage others to make healthy choices, access to traditional foods, contaminants from mine sites and the importance of teaching children about the environment.

Key Project Messages

1. A Frontline Training Course was developed to help with the communication of contaminant information. Much information has been distributed but problems exist in the communication and interpretation of this information within communities.
2. The course included discussions on contaminants in general as well as specific presentations on contaminant issues.
3. Participants compared the levels of cadmium in traditional/country food to levels found in cigarettes as well as Health Canada's recommended intake levels and found that people were generally not coming close to the maximum recommended intake levels through the food they eat.
4. Participants discussed ways to inform community members about contaminants information and to encourage communities to ask questions about the

information. A one-page information sheet to be brought back and posted in each participating community was drafted.

5. Recommendations were made for future workshops (e.g. inviting more people to participate, such as Yukon College and youth).

Objectives

1. Train frontline Community Health Representatives and other resource people on the dissemination of contaminants information in the 14 Yukon First Nation Communities.
2. Build on work begun during the first phase of the Northern Contaminants Program (NCP).
3. Continue discussions about traditional/country foods and health, and develop plans to continue to communicate to Yukon communities the recommendations from the Centre for Indigenous Peoples' Nutrition and Environment (CINE) dietary studies.

Introduction

Since 1992 a tremendous amount of contaminants information, particularly in the area of human health, has been distributed to Yukon communities. Yukon First Nations expressed concerns that communities do not have the capacity to interpret and communicate this contaminant information; they are worried about the dependence on outside researchers, from Whitehorse or the south, to communicate this information.

For the past several years the Northwest Territories and Nunavut have trained community representatives through a 3-day course developed by the Métis Nation-Northwest Territories. In 19990-2000, the Council for Yukon First Nations (CYFN) modified the course into a 2-day training session targeted at Yukon communities. All Community Health Representatives and First Nations were invited.

The Frontline Training Course was designed to provide background information to community representatives about the NCP and about contaminants in general, and also to provide an opportunity to learn about and practice writing proposals for funding from the NCP. The course was also designed to build on work begun during the first course of the NCP, to continue discussions about traditional/country foods and health, and to develop plans to continue to communicate to communities the recommendations from the CINE dietary studies. An aim of this Frontline Training Course was to have at least two community professionals attend from each community.

Activities in 2000-2001

The Frontline Training Course was held at the CYFN office in Whitehorse on February 28 and 29, 2001. More than 20 participants took part in the training.

Resource binders that were produced for participants for previous frontline training courses were reviewed and updated. The resource binders included information about the NCP, including the blueprint documents, proposal information and Guidelines for Responsible Research, a contaminants overview, information on northern food chains, traditional/country food fact sheets, benefit/risk communication information and Yukon Contaminants Fact Sheets.

Participants were informed of different contaminants activities and learned about some of the nutritional benefits of various traditional/country foods, as well as recommendations from the CINE study. Information about cadmium was presented and discussed, particularly in relation to elevated levels in some caribou in the Yukon. A draft Cancer Communications Information package was reviewed and discussed, and details were presented by Yukon Territorial Government staff about various funding sources for community health activities. To conclude the first 2 days, participants collaborated on an information page that they could take back to their communities to let them know what they had learned.

Following the Frontline Training Course, a half-day computer training session was held at Yukon College. This was held to facilitate the involvement of participants in on-line training opportunities, such as the CINE dietary course that is currently being developed.

Results and Discussion

The first morning of the Frontline Training Course focused on defining participants' expectations, providing participants with an update about the NCP's activities in the Yukon and internationally, and reviewing the CINE study highlights.

An overview and update of the Department of Indian Affairs and Northern Development (DIAND) Waste Management and Contaminants Programs was presented by B. Hartshorne, Manager of DIAND's Waste Management Program in the Yukon, and an Acting Manager of the Contaminants Program. Highlights of B. Hartshorne's presentation included an overview of the goals and activities of the Contaminants and Waste Management Programs, a map showing waste sites in the Yukon, and a listing of lakes where fish have been sampled for contaminants under the NCP.

A general overview about contaminants followed, using information from the resource binders. This served as a review for participants who attended the March 2000 training course, as well as a primer for those participants attending for the first time. Topics covered included long-range transport processes, the grasshopper effect, organochlorines, metals, radionuclides, biomagnification and bioaccumulation.

The afternoon of the first day was devoted to following up on recommendations made in the CINE dietary study (Receveur et al. 1998). Specifically, these recommendations stated that: "It is therefore recommended that health and nutrition programmes target women and emphasize the benefits of physical activity, traditional food use, and calcium and vitamin A-rich food sources. Attention should also be focused on the health and nutritional needs of elders."

These recommendations were highlighted in preparation for a detailed presentation by Laura Salmon, the Traditional/Country Foods Coordinator for the First Nations Health Program at the Whitehorse General Hospital. This presentation began with general information about healthy eating, which was summarized as follows:

- Enjoy a variety of foods.
- Emphasize cereals, breads and other grain products, vegetables and fruit.
- Limit salt, alcohol and caffeine.
- Choose lower fat dairy products, leaner meats and foods prepared with little or no fat.
- Achieve and maintain a healthy body weight by enjoying regular physical activity and healthy eating.

There was a discussion about traditional/country food versus market food, and the benefits of a diet that include both whenever possible. Food guides from different jurisdictions were introduced to conceptualize what eating a variety of foods "looked like" and how to practice that.

Following this general discussion, the presentation focused on calcium and vitamin A, including what they are, where we can find them, how much we need and what happens if we don't get enough. Ms. Salmon also mentioned other nutrients, such as vitamins C and E, folate, selenium, choline, beta-carotene and vitamins B_6 and B_{12}, highlighting the fact that there are many nutrients we need to maintain a healthy body. Nutrient fact sheets about calcium and vitamin A, produced in the NWT, were distributed, as were excerpts from Health Canada's Native Foods and Nutrition Guide for participants to include in their resource binders.

Participants then engaged in a round-table discussion about "Healthy Eating Messages" – what we want people to know, what tools we use to tell people about nutrition and what tools we need to promote healthy eating.

The focus of the second day was to continue to facilitate participants' ability to respond to community health concerns and issues related to contaminants. More specifically, there was discussion about cadmium, (particularly as it related to levels in Canadian cigarettes and some caribou kidneys and livers in the Yukon, and community concerns), the draft Yukon Cancer Information booklet, and sources of funding for various types of community projects. The last part of the afternoon was spent developing a short but useful message that participants could take home with them to inform community members about the course they had just taken, and where to go for more information.

Cadmium was discussed in response to community concerns raised at other meetings, notably a Health Commission meeting in November 2000 and an Elders Council meeting in December 2000. These concerns were related to information on the radio and in the newspaper about testing that was being done on kidneys and livers of caribou, as part of the NCP, and that some people thought this meant that caribou were unsafe to eat. With this in mind, a discussion about cadmium was included in the agenda. General information was presented about cadmium, including levels found in the Yukon (from the *Yukon Contaminants Curriculum*, *Book Two*: 29-33). Participants looked at cadmium levels in Finlayson caribou kidneys and livers in relation to cadmium levels in cigarettes; levels in the liver of the Finlayson herd caribou are higher than other herds because of naturally occurring cadmium in their region. Cadmium levels have likely been higher in this region than in most other places in the Yukon for hundreds of years, so these higher levels in caribou were not seen as a new concern for the caribou or the people.

The participants estimated that a person who smokes three packages of cigarettes a week for a year takes in 12 000 milligrams of cadmium, and a person who eats one liver a year from a 5-year-old caribou from the Finlayson herd takes in 180 milligrams per year. In other words, a person would be getting nearly 70% more cadmium from smoking three packs of cigarettes weekly for a year than they would from eating one liver per year.

Participants talked about how many caribou kidneys people between the ages of 20 and 40 might eat in a year, and the average was thought to be between one-quarter to one kidney each year. The response for moose liver was from zero to two per year, yielding an average of one, and for people between 40 and 60 years of age it was thought to be one to two per year. This was compared to Health Canada's recommended intake for cadmium levels, assuming caribou kidneys were eaten every year of one's life from the year of birth to the year of death. The recommendations stated that people should not eat more than eight kidneys per year from the Finlayson caribou herd, not more than 25 per year from the Porcupine caribou herd, and not more than 32 per year from the Bonnet Plume herd. In other words, people were generally not coming close to the maximum recommended intake, although there were still concerns being expressed by communities. Participants also discussed the fact that caribou liver is an excellent source of Vitamin A, protein and iron, and is low in fat. This helped to emphasize the fact that it is important to consider a good balance of information and to ask questions in these kinds of situations.

The discussions concluded with small group work to develop two or three plain language messages about cadmium that would be interesting to people. The messages were:

- Put on a big workshop and tell people to eat traditional/ country foods, about the effects of smoking, and that traditional/country foods have much less cadmium than cigarettes.
- Draw a scale with cigarettes on one side and caribou kidney/liver on the other. Weigh your options and use your common sense.
- Explain what cadmium is and that it is naturally occurring. Do the weighing comparison between caribou and cigarettes. Explain through posters and pictures, hands-on and visual aids that cigarettes are actually more harmful than eating a couple of livers or kidneys.
- Take the messages into schools. Explain to children that eating traditional/country food is good and that smoking is bad.

The majority of the afternoon session focused on various funding opportunities for community projects, particularly those involving youth and those related to health.

The course concluded with a group discussion about how to inform community members about the information learned during the Frontline Training Course and how to encourage questions about the information. After considerable discussion, participants developed a one-page information sheet that was to be posted in each community along with the CINE poster; participants took these back home with them.

Evaluations

Pre- and post-training course surveys were conducted to get an idea of what information participants had when they started the course, and what learning had taken place during the course.

At the beginning of the course, most participants knew that contaminants travel in ocean currents, rivers and wind, that contaminants levels in the Yukon are generally very low, that cadmium is mainly naturally occurring and has been in the Yukon for a long time, and that eating a variety of foods in moderation is important for our health.

The results of the post-course survey indicated that there was an increase in the number of participants that understood that "not all contaminants are harmful" and that more than half of the participants had spoken with at least three people in their community about the Frontline Training Course they had taken the previous year. All participants knew who to contact if they had questions or concerns about contaminants. Overall, participants rated the course as successful:

- 100% rated the workshop very good or excellent.
- 100% rated the course materials either very good or excellent.
- 100% rated the organization of the workshop and the instructor as excellent (7/9) or very good (2/9).

Recommendations for future workshops included involving Yukon College – Professional Studies, youth and more people who work in the lands and resource area. Participants' concerns about health and the environment included contaminants in traditional/country foods, cancer, high rates of diabetes, garbage and recycling, monitoring health, how to encourage others to make healthy choices, community members' access to traditional foods, contaminants from mine sites and the importance of children having information about the environment.

Project Completion Date

March 31, 2001

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State of the Environment 2000 – a First Nations Perspective on the Land and Environment for 2000

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Abstract

The First Nation of Nacho Nyak Dun Land and Resources Department received approval on a workplan that supports responsible environmental management and relates traditional knowledge with decision making and data collection. Through this workplan, as well as funding from the Northern Contaminants Program, workshops that focus on a First Nations perspective of the land and environment have taken place. This year's workshop, State of the Environment 2000, took place August 6-9, 2000, in Moose Creek, Yukon. It was geared towards 'sustainable communities' and allowing Elders to discuss traditional practices and express their concerns for today's and future generations. As well as an Elder's discussion, presentations were given by government and non-government organizations that relate directly or indirectly to contaminants in the North. During the discussions, Elders commented on the state of the environment, pollution, as well as traditional lifestyle. They expressed that First Nations people need to become one again and work together. Recommendations for follow-up to the workshop addressed the needs to gather further data, to continue to communicate regularly through workshops, to continue work on criteria and indicators for monitoring purposes, and to develop a program to determine options for environmental monitoring.

Key Project Message

- To ensure that traditional knowledge is preserved for future generations, it is important to understand Elders' perspectives on the land and environment, and have these views communicated to youth as well as government and non-government organizations.

Objectives

1. Build on the past and current contaminants-related programming delivered by the First Nation of Nacho Nyak Dun Lands and Resources Department.
2. Facilitate specific discussions to identify and record concerns and common interests related to contaminants in the food chain.

3. Facilitate discussions with Yukon First Nations in order to gain a better perspective of the state of the environment in Yukon from a traditional standpoint.
4. Allow Yukon First Nations youth and Elders to participate in 4 days of culture, learning and fun.
5. To work in cooperation with all Yukon First Nations to properly record and video the event so as to provide an accurate record of the proceedings.

Introduction

"Work together with the land to protect the environment for future generations"
Little Dave Moses, 1999

As demands for resources continue to increase, maintaining and sustaining a traditional lifestyle for future generations is becoming challenging. To ensure the protection and recognition of the values and traditions for future generations, First Nations communities must be involved in the planning, designing and decision-making processes on any developments with their traditional lands.

When Elders gather to discuss environmental concerns, discussions often focus on economic development and the effect it has had on the environment. The First Nation of Nacho Nyak Dùn Lands and Resources Department has developed a workplan, which was approved by the General Assembly in 1999, that deals with responsible environmental management and relates traditional knowledge with decision making and data collection. Elders need to play the lead role in determining how there can be responsible development in the future, while ensuring that cultures and traditions of First Nations are not compromised.

During the past few years, the First Nation of Nacho Nyak Dun Lands and Resources Department has been very proactive about building the capacity for responsible environmental management. In 1999-2000 the department received funding from the Northern Contaminants Program (NCP) to deliver Phase II of an introductory environmental assessment training program delivered by Royal Roads University of Victoria. A traditional knowledge workshop focussing on establishing research guidelines was held July 26-28, 1999, in Mayo, Yukon, and was considered a great success.

Due to the success of the first workshop, a second workshop was planned with its intent to involve Elders in identifying a process or a method to ensure their participation in developments within their traditional territories. The First Nation of Nacho Nyak Dun Lands and Resources Department has committed to establishing a Traditional Knowledge Oversight Committee to guide and steer traditional knowledge based programs for the department. By hosting this workshop in 2000, the First Nation of Nacho Nyak Dun Lands and Resources Department is initiating an Elder-driven process to design and develop an environmental monitoring program for the traditional territory.

Activities in 2000-2001

A traditional knowledge workshop, State of the Environment 2000, was held August 6-9, 2000, at Moose Creek, Yukon. The main theme of this workshop was "Towards sustainable communities...think 7 generations." All Yukon First Nations Elders and youth were invited to participate. Government and non-government representatives were invited to give presentations on their mandates and to communicate their activities pertaining to the environmental issues and concerns of First Nations people.

Results and Discussion

Approximately 30 youth and Elders participated in the State of the Environment 2000 workshop. To familiarize participants with the various government and non-government initiatives currently underway that pertain directly or indirectly to contaminants in the North, representatives of federal departments (Department of Indian Affairs and Northern Development [DIAND] and Environment Canada), the Government of the Yukon Territory (YTG), and two non-governmental organizations (Council of Yukon First Nations [CYFN] and Northern Climate Exchange) were invited to give presentations. These provided a brief description of the issues and activities in which each organization is involved as well as an overview of the different programs which they support.

The two presentations made by representatives of the CYFN explained the different programs with which the CYFN is associated (e.g. the Development Assessment Process, First Nations Forestry Program, and the Harvest Support Program), and explained Canada's Sustainable Development Strategy and the incorporation of the Northern Strategy. The YTG's Environment Branch described the *Environmental Assessment Act* and its connection with work on the Renewable Resources Program. Presentations by the Environment Directorate, DIAND, explained the *Canadian Environmental Assessment Act*, and the incorporation of traditional knowledge into this Act. The Waste Management Division, DIAND. presentation described the NCP, as well as the specific environmental baseline studies in the Yukon in which they are involved. A presentation by the Northern Climate Exchange gave an overview of climate change predictions and impacts. The final presentation, by the Ecosystem Health Officer, Environment Canada, reviewed environmental protection as well as sustainable development criteria and indicators.

As one of the main objectives of this workshop was to involve Elders in order to gain a traditional perspective on the state of the environment in the Yukon – an Elders' discussion was held on the second day of the workshop. They noted many different concerns and priorities, such as changes to the environment and the confusion associated with such changes, pollution issues, the need to limit animal harvests, as well as the need to promote communication between Elders and youth. Elders feel that it is important that youth are open to asking questions in order to learn more about their culture; it is important that youth understand how families worked together as one, there no boundaries between families or communities. A full report on the issues covered during the workshop can be found in the workshop report (First Nation of Nacho Nyak Dun 2001).

Conclusions

The following recommendations were identified for follow-up to the workshop:

1. Gather further data on climate change and the environment in general.
2. Communication between First Nations and the different levels of government should continue regularly through additional workshops.
3. Continue work on criteria and indicators for monitoring purposes.
4. Develop a program to determine options for environmental monitoring (e.g. in conjunction with guiding and wilderness tourism).

Project Completion Date

March 2001

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First Nation of Nacho Nyak Dun. 2001. *"State of the Environment" 2000 A First Nation Youth and Elders Perspective on the Land and Environment for* 2000. Mayo, Yukon: 9 pp.

Avatiptinnit Niqittiavait – *Good Food in the Environment*

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Abstract

This project makes an important step toward realizing some key objectives for contaminant communication and education in Inuit communities. By methods of regional workshops and direct Inuit participation and input from five regions (Inuvialuit, Kitikmeot, Kivalliq, Qikiqtaaluk and Labrador), this project will use a process of "community dialogue" to evaluate and interpret the data of the Centre of Indigenous Peoples' Nutrition and Environment's Dietary Benefit-Risk Study from an Inuit specific perspective. This community dialogue will help to assess the significance of the study's findings on: Inuit subsistence practices and diet; market food consumption; the risks and benefits to health; the potential impacts of lifestyle decisions on culture, economy and community; the use of research; and approaches to communicating with and educating communities about contaminants issues. Ultimately, this project will provide Inuit with the appropriate information on the benefits, risks and importance of traditional lifestyles to assist individuals and communities in making informed decisions about harvesting and consumption of northern foods. It will do this by using different communication methods such as regional workshops, a Web site, radio shows, newsletters, community tours and posters to provide Inuit with a current, comprehensive and accessible body of relevant information, enabling them to have more control over contaminants-related issues and problems. This year's (2000-2001) communication efforts were concentrated in the Labrador and Inuvialuit regions. In 2001-2002, communication efforts will be in Nunavut. The project will conclude in 2002-2003.

Key Project Messages

1. Communication efforts on the subject of dietary benefits and risks concentrated in the Labrador and Inuvialuit regions in 2000-2001; communication efforts in Nunavut will take place in 2001-2002.

2. The key messages that were delivered in the Labrador and Inuvialuit regions were:
   - Contaminants are relatively low in these regions.
   - Eat more traditional foods; a diet of traditional foods provides a healthier lifestyle compared to a store-bought food diet.
   - The younger generation (especially young women) are consuming an unhealthy diet.
   - Obesity is rising and may become a serious health factor.
   - Eat less junk food from the store.

Objectives

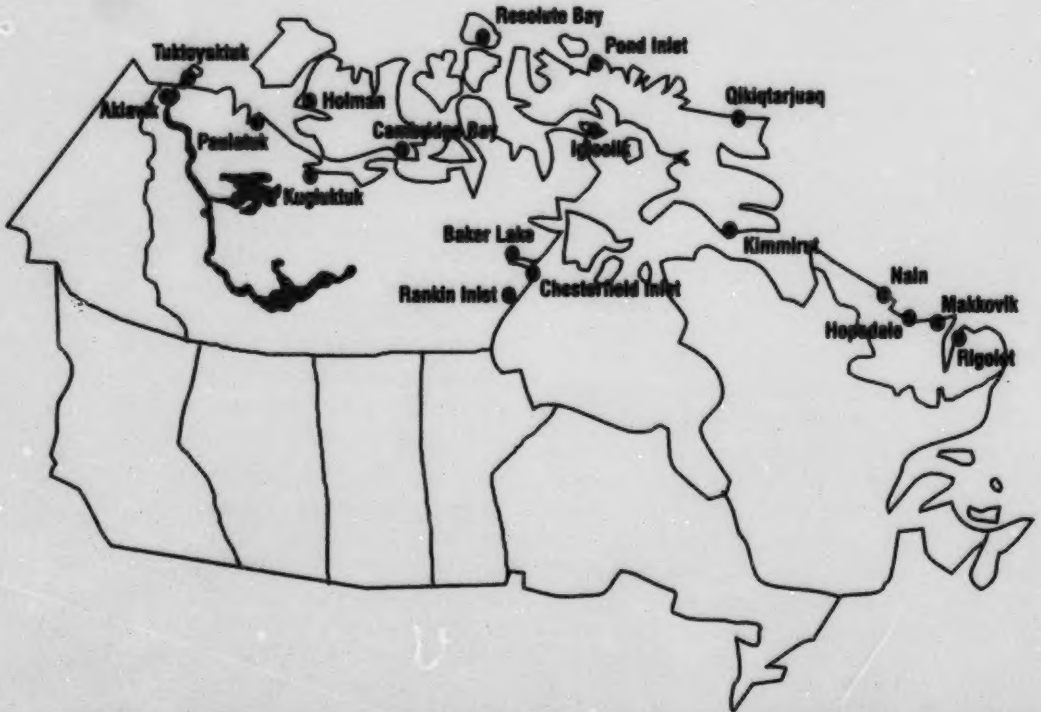
1. Evaluate and interpret the data of the Centre of Indigenous Peoples' Nutrition and Environment (CINE) Dietary Benefit-Risk (DBR) Study, with the input of Inuit representatives from the five Inuit regions (Inuvialuit, Kitikmeot, Kivalliq, Qikiqtaaluk and Labrador).
2. Identify and establish culturally sensitive approaches for delivering the results of the DBR Study to Inuit.
3. Package the data of the DBR Study in the most effective and appropriate manner for communicating with and educating Inuit residents of the five Inuit regions about the findings of the study.
4. Establish a process of community "dialogue."

Introduction

As the national voice for Inuit in Canada, the Inuit Tapirisat of Canada (ITC) has played an important role as an advocate for Inuit interests on contaminants issues for a number of years. One of ITC's current objectives is to facilitate the communication of contaminants research for Inuit. The Environment Department of the ITC is responsible for the communication of the recently completed study: Assessment of the Dietary Benefit/Risk in Inuit Communities Project. This research was conducted by CINE and took place from 1997 to 2000 in five Inuit regions (Qikiqtaaluk, Labrador, Kivalliq, Kitikmeot and Inuvialuit).

In the CINE study, quantitative estimates of traditional and market food intake among Inuit in the five regions were derived in order to characterize exposure to contaminants and the multiple benefits of traditional food use. Eighteen communities (Figure 1) were selected through regional workshops with community leaders and health professionals during 1997-1998 to represent these five regions. Nunavik (Northern Quebec) was excluded from the

Figure 1. Participating communities in the project Assessment of Dietary Benefit: Risk in Inuit Communities



original CINE study because a similar Northern Contaminants Program (NCP) funded study was already being done in that particular region. Therefore, Nunavik is not included in this project.

The CINE study was conducted in three phases. During the first phase, five regional workshops were held and a total of 39 communities sent representatives to develop methodology, identify participating communities, identify the extent of traditional food used seasonally by all communities, and determine the types of interviews to be used and the food samples to be collected for contaminant and nutrient analysis (Kuhnlein 1999a).

During the second phase (1998-1999), research agreements were negotiated with each community identified at the workshops, and pilot testing of the interview tools was completed in Shingle Point, Northwest Territories, and Igluligaarjuk (Chesterfield Inlet), Nunavut. Interviewers were hired and trained, and households were selected. The interviewing periods extended from October to December, and January to early April. Data collection for the study was successfully completed in all 18 communities by April 1999. In total, over 1929 interviews were conducted, and approximately 200 food items prepared for consumption were sampled and analyzed for nutrients and contaminants (Kuhnlein 1999b).

In the third phase (1999-2000), laboratory and data analyses were completed. The draft report was produced and presented at a workshop with 16 Inuit leaders to identify any errors and to develop a plan for the future communication of results back to the communities (Kuhnlein 2000).

Now that all the community data has been collected and compiled in a report (Kuhnlein 2000), ITC is working on communicating this data to Inuit in all communities. The first step was to take this data and compile it in a form that would be easily explained to everybody on a region by region basis. Once all the regions have been informed (project still under way from 2001 to 2003 in Nunavut), this information will be available through a number of sources: newsletters, published on a bi-monthly basis; regional workshops; radio shows; posters; a Web site and CD-ROM. Through this project we hope to support and develop community initiatives to improve nutrition, monitor the presence of contaminants, promote the benefits of traditional food and help individuals make better informed decisions about the food they eat.

Communicating the DBR Study using culturally sensitive and practical approaches will foster a better understanding and awareness about the study's findings among producers and consumers of traditional/country food. These approaches are intended to assist in enhancing individual and community capacities to make informed lifestyle decisions. The overall project will provide Inuit at the local, regional and national levels with a consistent, accessible and comprehensive body of relevant and current information. It will enable Inuit to own, control and utilize their specific contaminants-related data for the purposes of seeking solutions to contaminants-related problems. This project will also contribute to a more comprehensive and widely accepted set of criteria by which scientific and public health information is researched, developed and communicated by Inuit and non-Inuit within Inuit communities.

Activities in 2000-2001

ITC has identified a number of communication methods that will serve to deliver the objectives of this project. These methods were defined through direct discussions and recommendations given during past meetings and workshops with Inuit from the five regions, including the experience that ITC has gained through the work in which it has been involved in the last 3 years. The methods will incorporate the use of Inuit knowledge on the dietary benefits and risks associated with contaminant levels found in traditional/country food, and the benefits and risks associated with the consumption of market food. Because direct, face-to-face discussion and interaction is key, ITC is investing a major portion of this project toward the delivery of one workshop in each of the five participating Inuit regions.

In 2000-2001, ITC held two regional workshops: one in the Labrador region and the other in the Inuvialuit region. ITC also developed the foundation for a Web site for private use only, and will launch the completed version in 2002-2003. Pre-recorded and packaged radio programs, project newsletters, a promotional poster and media coverage elements have been used during select periods within the first and second year of this project to reach the widest audience possible. A CD-ROM will be modified and produced based on the Web site and distributed during the third year. A final report will be written after the fifth and final workshop in early 2003.

Results

Labrador and Inuvialuit regional workshops

In 2000-2001, ITC held two regional workshops: one in the Inuvialuit region and the other in Labrador. Each workshop brought together many of the same individuals who were instrumental in the development of the CINE study. Delegates at the workshops discussed their views on the accuracy of the CINE data results, the best methods of data dissemination, alternative ways to decrease exposure to contaminants, and weighing the benefits and risks associated with a diet of traditional/country food. These workshops not only provided information about the project but also presented important information about contaminant studies in general, addressed concerns about cancer, provided information about who to talk to about water quality, discussed concerns about climate change and presented reasons for animal abnormalities. The following are some of the questions and concerns that participants had prior to the workshops:

- What are considered high-risk contaminants?
- How does the future look for the next generation?
- Who is responsible for watching for contaminants? Is anybody getting training related to contaminants? What kind of training?
- Can we look into getting funding to carry out research on contaminants in each community? In the future, can our people learn how to study on an on-going basis contaminant issues. How can we make this happen?
- Is the world as a whole working together to improve our contaminants problem? If so, what countries actually get involved? Why?
- As a northern resident, I do not see our people fighting to clean our land, fighting back to get our land cleaned; is this because they are unaware or uneducated? We should be fighting to keep our land clean. Together we can get things done.
- What would it take to wake up Inuit to see what is happening to our land?

Suggestions and questions after the workshops

Workshop participants were given an opportunity to comment on the knowledge they had gained through the workshops, ask questions that had not yet been answered and provide suggestions. Participants stated that they learned that their traditional/country food is still safe and healthy to eat, and that it is important for all Inuit to receive this message. Traditional/country food is healthier than junk food, as it keeps Inuit healthy and active, provides nutrients particularly important for prenatal nutrition and may help to prevent some cancers. Although they understood that their food is safe to eat, the participants also recognized that their food needs to be monitored for contaminants, and that these studies will provide communities with the information they need to make decisions about their food use. Participants learned about what contaminants are and where they come from, as well as how levels in communities compare on a regional and national basis. They learned about "tolerable daily intake" for people and possible effects from contaminant exposure. Observed abnormalities in animals may be linked to climate change as opposed to contaminants. Contaminant exposure may be limited by certain cooking methods and by eating less traditional/country food during the first trimester.

Overall, participants were pleased with the information presented at the workshops and the opportunity to have their questions answered and their concerns addressed, particularly concerning the foods they eat. One participant stated, "It was great to share ideas with other communities and to listen to concerns raised and being put at ease." Another participant commented, "I have attended previous workshops on contaminants in the past and this was by far the most interesting, informative and knowledgeable." Participants emphasized that the information presented at the workshops must get out to all Inuit and recommended simple posters that everyone can understand and community tours as means of communication.

The workshops in both the Inuvialuit and the Labrador region provided suggestions for what people can do about this problem of communication of contaminant information and the benefits of consuming a traditional food diet.

- "Teach the information about contaminants at the schools and other health programs."
- "Help people understand that traditional/country food is better and to talk to kids."
- "Prepare pamphlets, posters and talks to teach others what we've learned."
- "Continue to eat native foods and eat less store bought foods."
- "Be active and inform people about the information that I've learned."
- "Teach people back home."
- "Find out who can answer the people on contaminant issues and keep in touch with Parliament or our MLA."

Following each workshop, a summary report was produced outlining the views, concerns and recommendations of all delegates. These summary reports, taken together with those of the three workshops in the following year, will provide a comprehensive collection of Inuit regional perspectives on which to base the development of the final report.

Preliminary meetings with Regional Contaminant Coordinators

Meetings were held with the Regional Contaminant Coordinators (RCCs) to discuss this report and to strategize the best ways of delivering the information to their regions.

There is a lot of concern that this report is filled with numbers (statistics, graphs, percentages and so forth) which are difficult for many community people to understand. Therefore, the RCCs gathered together and developed ways of communicating this information as listed below:

- Strategize, plan and outline the content elements and activities of the communications methods that will be used throughout 2000-2001.
- Finalize or adopt a general work plan of activities and target dates for 2000-2003.
- Appoint spokespeople, facilitators, presenters and technical resource people for the two workshops in 2000-2001.
- Establish a draft agenda.

RCCs also reviewed and finalized the DBR Study and other CINE documentation.

Development of the Avatiptinnit Niqittiavait Web site

ITC developed a preliminary and private ITC Internet site in order to provide client partners with a common and accessible reference site for discussing, evaluating and updating the DBR Study and project information. The Web site will be useful for teleconference meetings and other distance discussions.

Schools reviewed this Web site during the two community tours in the Western and Eastern Arctic in January 2001. They provided evaluations on the ease of navigating through the Web site, clarity of content information and general evaluations.

Once the information becomes solidified in 2002, the site will be incorporated into ITC's current contaminants Web site for public access. The results of this project and current developments on contaminant benefits and risks will be updated on the ITC contaminants Web site.

As a spin-off from the project's Web site, ITC will produce and distribute a project CD-ROM in the 2001-2002 year. The CD-ROM will be distributed for general reference and educational purposes and for the use and purposes of the participating Inuit regions.

Radio programs

ITC produced an information radio program that informed the regions about the completion of the project, upcoming workshops and some key messages of the DBR Study. As well, regional-specific radio programs gave residents of each region an opportunity to hear the responses, concerns and issues from the workshop that are specific to their regional communities.

Newsletters and posters

ITC published and distributed four project-specific newsletters during 2000-2001. Information in this newsletter provided information on the background, activities, achievements and up-coming events of the project on a quarterly basis. It also provided a forum for the RCCs to communicate to their region as well as nationally.

ITC also produced a poster in limited print in the year 2000-2001. The poster promotes the use of traditional foods and shows the nutrient value of some of the major traditional food sources, such as caribou. As well, posters are being produced from each of the regional workshops. Eventually when all of the workshops are completed a single poster will be made consisting of the five regional posters. This will provide Inuit with a poster that, in their words, represents the key points that this project has to offer.

In Labrador, the key message was "Country Food is Good For You!" This slogan was made into a poster that shows images of wildlife in Labrador and the many reasons why hunting and traditional/country food are good for the people of Labrador. In the Inuvialuit region's poster, the delegates wanted to demonstrate the importance that traditional/country food has on their culture. Another poster that they developed is aimed for children to cut back on their consumption of sugary store-bought foods like soft drinks and candy bars.

Discussion

This project is unique in that it provides for Inuit involvement in the analysis, evaluation and dissemination stages of the DBR Study. Furthermore, this project is significant because it has the potential to educate researchers, public officials and Inuit about culturally appropriate methods of communicating contaminants-related information to Inuit communities. The communication of the research will go a long way in answering some of the concerns about the potential health risk and benefits of traditional/country food, as well as the competing risks associated with other food sources. It will address medical impacts of dietary and lifestyle changes, and the social and economic impacts of restricting traditional/country food consumption.

ITC is particularly concerned with ensuring that Inuit have appropriate information on the risks, benefits and importance of traditional lifestyles to make informed decisions about the harvesting and consumption of Inuit country food. The need for Inuit involvement in the evaluation of research data and the development of culturally-sensitive communication strategies is particularly important when dealing with the results of dietary studies because of the immediate linkages to Inuit health, nutrition, culture and economy.

The concern about Inuit health risks from contamination raises a parallel concern about the threat to the continuance of the subsistence lifestyles and diet of Inuit. Subsistence harvesting and diet are integrally linked to the overall identity, culture and way of life of Inuit. The crux of this matter was addressed at the Eastern Arctic Workshop in December 1998. At the time, Inuit Elders called for a balanced approach that will weigh the potential health risks against the known benefits of subsistence harvesting and diet, and still maintain the cultural identity and total health and well being of Inuit. They expressed that a potential fear factor about contaminants may outweigh the knowledge about actual risks posed by contaminants, thereby causing greater harm.

Sending the wrong message through improperly conceived educational and communications campaigns can have serious ramifications. For example, such messages can misinform Inuit to reduce their consumption of traditional/country food and the nutritional benefits therein, and in turn increase their consumption of non-traditional foods that have other potential health risks. Food consumption advice, therefore, should occur within a broader public health context that includes a balanced consideration of risks and benefits to Inuit.

Usher et al. (1995) and Furgal et al. (1995) have documented the need to develop and evaluate culturally appropriate communication strategies. There exists much literature to guide the development of effective strategies and messages for risk communication in the South (Covello et al. 1989, National Research Council 1989). Many aspects of communication and education are well developed through the use of radio, workshops, videos and fact sheets. However, the establishment of proven communication methods on dietary risks in the North is still in its infancy. Many lessons have been learned from case study analysis of communication on health advisories related to chemical contamination in traditional/country food in Aboriginal communities (Usher et al. 1995, Peters and Legare 1999, Furgal 1999). Some research has been carried out to understand better, from the perspective of northern communicators and local residents, the unique challenges of benefit-risk communication and education in the North, about information needs and people's perceptions of risks and benefits related to environmental contaminants (Usher et al. 1995, Poirier and Brooke 1999, Furgal 1999). In its entirety, this information provides a basis upon which to begin identifying ways to communicate effectively within Inuit communities on environmental and health issues.

The NCP itself explicitly recognizes in its education and communication components that there is a need to shift away from an earlier model of "dissemination of scientific data to the public" to one of community "dialogue." This shift can assist in increasing capacities and enhancing expertise on contaminants-related issues at various levels and, as well, striking partnerships among Inuit communities, scientists, public officials, the NCP and Aboriginal organizations. This project is a major step forward in discovering appropriate and useful means of returning information so Inuit can begin to answer the question "What does this all mean to me?"

Conclusions

The results of the DBR Study make it very clear that traditional/country food of the Inuit provides a rich nutritional and cultural resource. Traditional food used by Inuit provides multiple cultural, social and economic benefits, in addition to substantial nutrient benefits. The effects of losing these benefits as a result of decreasing use of traditional foods are potentially life threatening in several ways, including impacts on physiological and mental health. Therefore, it is essential that the communication of the results of this project continue to reach Inuit via many different mediums, i.e. workshops, radio, newsletters, Web sites, as well as reach out to as many different audiences as possible, such as Elders, youth, health care workers and wildlife experts. This will ensure that Inuit have the appropriate information on the risks, benefits and importance of a traditional lifestyle in order to make informed decisions about harvesting and the consumption of country and store bought foods.

The workshops conducted in the Labrador and Inuvialuit regions during 2000-2001 were highly successful in providing Inuit with answers concerning the myriad of questions that they had concerning their diet and contaminants. Participants stated that they learned a lot at these workshops and were happy with the way that the workshops presented information and promoted interaction.

Expected Project Completion Date

This project will be completed after all of the five regions have been informed via workshops, and/or community tours. Two workshops in Nunavut are planned for 2001-2002, and one more for 2002-2003. A final report will be completed by April 2003.

Acknowledgments

ITC would especially like to thank the RCCs in Labrador and in the Inuvialuit region for their help and guidance with this project, especially with the workshops. Jimena Tovar of CINE was indispensable for translating the "big yellow book" into information that was useful at a community level. Chris Furgal provided endless support and advice. ITC would also like to thank Roberta Baikie, Autumn Watson, Craig Clark and all of the community members who have provide excellent suggestions throughout the course of the year.

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Training and Support for Regional Contaminant Coordinators

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Abstract

Regional Contaminant Coordinators (RCCs) facilitate two-way communication between the Northern Contaminants Program and northern communities. They are also expected to engage in capacity building activities for dealing with contaminant issues. A training workshop was held at the Inuit Tapirisat of Canada offices in Ottawa, March 22-24, 2001. Participants included RCCs from Labrador, Nunavik, Kivalliq and Baffin regions. The workshop dealt with an overview of the RCCs' responsibilities, including evaluating communication priorities, developing educational materials, organizing workshops, time and budget management strategies, proposal writing and research licensing procedures. The workshop also provided an opportunity for the RCCs to meet face-to-face and set up their own communication strategies for networking among themselves. They also provided recommendations for future workshops to extend their own professional development. All participants were provided with an RCC Reference Manual and a CD-ROM version of all the reference materials used in the workshop.

Key Project Messages

1. Regional Contaminant Coordinators (RCCs) are a key link between the Northern Contaminants Program (NCP) and the residents of the North.
2. Information regarding NCP activities must be provided to communities in a clear, well organized way, in non-technical language.
3. RCCs must be well informed so that they can deal effectively with issues of concern for their regions.

Objectives

1. Provide RCCs with an overview of the scope and findings of the NCP.
2. Provide training and support for RCCs and to clarify their role within the NCP.
3. Provide RCCs with an opportunity to develop networking strategies.
4. Help to provide consistent messages to northern communities with regard to the findings of NCP research and projects.

Introduction

RCCs have been identified by the NCP as key people who have the capacity to bring the program closer to the North and to bring community questions and concerns to NCP management. RCCs have the expertise to do this because of their knowledge of the culture, people and geography of their regions. However, it is also important for them to be familiar with the NCP's structure, organization and procedures, as well as with general contaminant issues and specific issues and events in their own regions.

The development of RCC positions is an important step towards achieving effective two-way communication between the NCP and northern communities. The RCC workshop provided an opportunity for these coordinators to get to know one another and share ideas, experiences and knowledge. The workshop covered many aspects of the RCCs' responsibilities, including important logistical tasks such as time and budget management strategies, and organizing workshops, as well as background information about the NCP structure and its findings on contaminants, as published in the *Canadian Arctic Contaminants Assessment Report*, using the Highlights Report, evaluating communication priorities, developing educational materials, and proposal writing and evaluation.

Activities in 2000-2001

In March 2001, the RCC manual produced by Métis Nation-Northwest Territories was updated in preparation for the workshop. Revisions were made based on recommendations from the last RCC training (Farrow 2000) session and consultations with E. Loring of the Inuit Tapirisat of Canada (ITC) and Carole Mills of the Department of Indian Affairs and Northern Development (DIAND), Yellowknife. The manual was prepared as a hard copy in a three-ring binder for use during the workshop and in a CD-ROM format. All participants received both the CD-ROM and a hard copy.

The workshop was held March 22-24, 2001, at the ITC offices in Ottawa. Participants included RCCs from Labrador, Nunavik, Kivalliq and Baffin regions. During the workshop, participants took part in developing a number of templates for reporting procedures and management strategies. The small number of participants meant that topics covered could be tailored to individual needs. All participants were encouraged to freely discuss concerns and share their experience and expertise with the group. Time lines for NCP activities were discussed and work plans for the 'NCP year' were developed. Table 1 outlines the topics covered during the 3-day workshop.

Results and Discussion

The RCC workshop was well received. RCCs often feel as if they are working in isolation so the opportunity to meet with others, face-to-face, who deal with similar challenges was useful. However, it was clear from the discussions that more time should be allotted for this training. There is a need to include background information, such as that delivered by the Frontline Training course. In their overall evaluation, RCCs felt that the workshop provided much needed tools and information, although some discussions and activities were curtailed due to time constraints. The need to be well informed of NCP activities was strongly expressed.

Conclusion and Recommendations

All participants agreed that the training was useful and the following recommendations from the group are offered for consideration in the future:

- More time and/or more workshops are needed to cover all of the material thoroughly. In particular, more time must be spent on proposal development.
- RCCs should meet more than once a year.
- Consider holding RCC training in conjunction with a Frontline Training course.
- Ensure that the workshop is held at a time when it is reasonable to expect that all RCCs have been hired.

Project Completion Date

March 31, 2001

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Table 1. NCP Regional Contaminants Coordinator Workshop outline, March 2001

Objective	Content	Duties
RCC will:		
• Make contact with other RCCs, resource people	• Introductions	• Contacts
• Review RCC role and job description	• Job description • Deliverables • RCC Manual	• Read
• Understand the structure of the NCP and general contaminants information	• NCP structure • Role of Aboriginal organizations • Communications • Contaminants overview	• Background information
• Decide how to initially engage community audience and contact scientists, managers, etc.	• Contacts outside and within the region • Communication vehicles • Offering workshops/ information sessions • Offering assistance to scientists	• Promoting one's position in order to be able to act as a conduit for two-way info exchange between communities and NCP. • Liaising with local/regional boards
• Consider how best to communicate material to specific audiences	• General contaminants information • Communicating to specific audiences: translation (glossaries) one-on-one, etc.	• Promote contaminant info and respond to local requirements.
• Develop a strategy for organizing a workshop	• Organizing a workshop/ information session	• Provide workshops/updates at assemblies and meetings where appropriate
• Initiate research on a community question/ concern	• Steps for pulling together research information • Resources, contacts (manual)	• Promote contaminant information • Respond to local requirements
• Explain how to proceed	• What to do about gaps in information (proposal ideas)	• Develop regionally relevant resource material
• Develop material that can be used to communicate	• Resource materials available: graphics, etc.	• Develop regionally relevant resource materials
• Identify NCP and non-NCP questions and concerns	• NCP mandate • Other programs • Site-specific programs	• Facilitate communication of community concerns to the appropriate level • Assist communities/regions to identify research priorities related to contaminants
• Explain procedure for proposals	• NCP blueprints • Proposal format	• Assist communities/regions to develop research ideas and proposals for NCP and other funding bodies
• Determine whether or not a proposal will be accepted by the NCP and why.	• NCP blueprints	• Same as above
• List contacts available for assisting in proposal development.	• NCP blueprints	• Same as above
• Be aware of licensing requirements	• Licensing requirements for Nunavut and NWT	• Same as above
• Act as a contact for NCP researchers	• Community consultations • Reporting project results • Negotiating research agreements	• Act as contact for NCP researchers • Assist with community consultations for project proposals • Assist researchers reporting project results back to communities • Assist in negotiation of research agreements for funded projects
• Review a budget • Create a budget	• What funding is available for • Using budgets productively • Going over, going under • Other funding	• Adhere to funding levels; identify other funding programs
• Review deliverables • Create a report	• Activity reporting requirements • Examples of communications materials previously produced	• Attend and present regional reports at the NCP Results Workshop • Mid-term and final reports
• Evaluate the course	• The past two days	

Northern Contaminants Poster Contest

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Abstract

Children and youth are one of the key audiences that the Northern Contaminants Program has identified as requiring focus for further efforts to communicate contaminant information. Educating students on contaminant issues and then encouraging them, through a poster contest, to create their own posters is one way in which children and youth are able to express to others what they have learned. These posters then can be displayed at schools across the North and elsewhere in Canada. Posters from schools in the Yukon, Northwest Territories and Nunavut were submitted to either the Council of Yukon First Nations, Dene Nation or Inuit Tapirisat of Canada, and then were judged by a team consisting of a representative from each organization. The schools that provided the first, second and third place posters received $3000, $2000 and $1000, respectively, worth of science-related educational material. The winning poster will be printed and sent to schools across the North and major centres across Canada, as well as to Band Offices, Tribal Councils, museums and other northern locations. From the posters that were created, it was possible to gain a better understanding of the extent of understanding that students have on contaminant issues. This contest showed that students are receiving good information and that current education efforts should continue.

Key Project Messages

1. Through information provided to teachers and a poster contest, students were encouraged to create posters that expressed their own impressions of contaminants.
2. Posters were judged and the winning posters will be distributed to schools across the North and other select locations.
3. The posters were a useful indicator of the extent of contaminant information reaching students; they showed that good information is being communicated to this audience.

Objectives

1. Educate students across the North about contaminants by having them develop posters on contaminants issues.
2. Judge and select a winning poster design, have it printed and distributed to schools across Canada.

Introduction

A lot of research has been done in the North on contaminants and contaminant-related issues. Despite the efforts of researchers and the Northern Contaminants Program (NCP) to communicate such information to Northerners, few communication efforts have been directed specifically to children and youth.

The NCP Blueprint on Education and Communication states that one goal of the Education and Communications sub-program is to communicate results of NCP research and general contaminants information to target audiences and/or messengers (Northern Contaminants Program 1999), with children and youth being one of the key audiences. One of the specific recommendations for new proposals is to develop programs for youth and children.

Holding a poster contest encourages students to learn about contaminants and allows them to describe what they have learned in their own words and illustrations. As well, it provides a product that could be distributed to other schools across the North, as well as the rest of Canada, while providing much-needed books and software to schools with the winning posters.

The Métis Nation-Northwest Territories and the Yukon Contaminants Committee have developed excellent curricula for northern schools relating to contaminants (Métis Nation-Northwest Territories 1995a, 1995b, 1996, Yukon Contaminants Committee 2000a, 2000b, 2000c). This project was intended to build upon the information that has already been developed.

Activities in 2000-2001

Schools were provided with the information that was needed to educate students about contaminants in the North. Schools in the Yukon submitted their posters to the Council of Yukon First Nations; schools in Nunavut and the Inuvialuit region sent their posters to the Inuit Tapirisat of Canada; and schools in the rest of the Northwest Territories sent their posters to the Dene Nation. The top three posters from each territory were selected and a final judging was conducted by a team consisting of a member from the Dene Nation (Karen McArthur), Inuit Tapirisat of Canada (Scot Nickels), and the Council of Yukon First Nations (Cindy Dickson). The contest was open to students of all ages.

The winning poster will be printed and sent to schools across the North and to schools in major centres across Canada. It will also sent to Band Offices, Tribal Councils, museums and other locations across the north.

The school that provided the winning poster receives $3000 worth of science books and software for their library; second and third place receive $2000 and $1000, respectively, worth of science-related materials.

Results and Discussion

This project involved schools across the North and provided teachers with an opportunity to introduce the issue of contaminants in the North to students using information that has already been developed, by the Métis Nation-Northwest Territories and the Yukon Contaminants Committee. At the same time, the project provided students with an opportunity to share what they had learned with others through posters which they had designed themselves.

More than 90 excellent posters were submitted for judging and it is intended that all the posters that were created will be published in a scrapbook that would be made available to schools across the North. The overall winning poster, by Shevonne Bergeron, a Grade 6 student at Jack Holland Elementary School in Whitehorse, Yukon, is a colourful depiction of contaminants cycling through the air, water, fish, birds, terrestrial mammals and people (Figure 1), and includes an essay on the back of the poster. The second place poster, by Lenny Fabian, a Grade 4 student at Chief Sunrise Education Centre in Hay River, NWT, depicts the ecosystem exposed to contaminants and pollution of all sorts (Figure 2). The third place poster, by Jeanine Arey, a Grade 11 student at Helen Kalvak Elihakvik School in Holman, NWT, shows eerie images of specific contaminants (Figure 3).

The posters proved to be a useful indicator of the level of knowledge of contaminant information that students have gained. From the posters, we were able to see that good information is reaching this audience and that students are understanding the contaminant issues that are being discussed with them. Also evident in the posters

Figure 1. **Northern Contaminants Poster Contest: First place, by Shevanne Bergeron, Grade 6, Jack Holland Elementary School, Whitehorse, Yukon**

Figure 2. **Northern Contaminants Poster Contest: Second place, by Lenny Fabian, Grade 4, Chief Sunrise Education Centre, Hay River, Northwest Territories**

are the regional and cultural differences in the ways contaminant information is depicted by young students.

Expected Project Completion Date

This project will be completed once the posters have been distributed to schools in 2001-2002.

Acknowledgments

We would like to extend many thanks to all the schools that submitted posters and special thanks to the teachers who encouraged students to create and submit such impressive posters.

Figure 3. Northern Contaminants Poster Contest: Third place, by Jeanine Arey, Grade 11, Helen Kalvak Elihakvik School, Holman, Northwest Territories

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Frontline Training Course for Community Representatives in Labrador

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Abstract

Labrador Inuit Association (LIA) Research staff provided a 3-day Frontline Training course for staff of LIA and its affiliates to help enhance capacity in dealing with contaminant issues at the community level. The draft course manual, developed by the Métis Nation-Northwest Territories, was adapted for the Labrador region. Participants in the workshop included LIA field-workers, Labrador Inuit Health Commission, community health workers and public health aides, youth, community representatives from Makkovik, OKalaKatiget Society radio and TV staff, and Town Council of Nain representing the five north coast communities of Labrador. Participants were introduced to the issue of contaminants, the Northern Contaminants Program (NCP), northern nutrition, LIA Research communication guidelines, recent research on contaminants and benefits of traditional/country foods in northern Labrador, and scientific research/proposals. They became familiar with contaminant issues in northern Canada, learned ways of interpreting and communicating contaminants information, reviewed research methods, were empowered at personal and community levels in decision-making, and compiled a Labrador list of resources to be utilized in north coast communities. Participants also learned about the excellent value of traditional/country foods in Labrador as compared to store-bought foods; this included the nutritional, economic, and cultural benefits. The "workshop" format for the delivery of the course proved to be beneficial for participants. The course evaluation completed by all participants showed favourable results overall.

Key Project Messages

1. The Frontline Training Course for Community Representatives in Labrador was successful in its goal of providing baseline information to community representatives who are responsible for communicating health, environment and contaminant issues.

2. The course manual, a revision of the Frontline Training Course for Northern Community Professionals (Farrow 2000), enabled participants to take information back to their communities to be used as a resource. This manual covered a basic introduction to contaminants and the North. It also included northern nutrition, research methodology, communication guidelines and research results for the region.
3. The plain language format of delivery, the opportunity to have community concerns addressed by researchers present at the course, and the interest in the course by participants all contributed to the overall success of the course.

Objectives

Short-term

1. Ensure that community representatives have baseline information on contaminants information, research, and research methodology.
2. Provide information on community rights as they relate to research conducted by outside researchers.
3. Introduce the new licensing process developed by LIA Research for the Labrador region.
4. Raise awareness and understanding to empower community representatives in their role and involvement in health and environment research in their community and region. This will support and enhance their ability to access and deliver information and address community questions and concerns on these issues.

Long-term

1. Use the workshop as a foundation for capacity building by establishing basic knowledge among community representatives so that they may address the growing communication and educational needs of their communities.
2. Enable participants to be prepared for the settlement of a final land claim when Labrador Inuit will be responsible for governing many of their own affairs.

Introduction

Community representatives and residents continue to express concern about information on health, the environment, and contaminants that is not presented in a plain language format, and the lack of tools available to them for accessing information. In order to address the needs of the community, community representatives who are involved in research and communications urgently need training that provides them with baseline information. All five communities on the coast of Labrador are small, isolated and are predominantly Inuit. The community representatives often perform beyond their employment duties and are responsible for dealing with local concerns in an isolated environment, with little baseline information due to the lack of research conducted in Labrador. While this is a disadvantage for the region, the timing of a training workshop would enable community representatives to be prepared for upcoming research activities. Community representatives would benefit from a workshop because of the similar needs of their communities.

Community representatives need to be knowledgeable about the most up-to-date information, able to deliver information that is relevant to the community and/or region, know what kind of research has been conducted in the region and know how to communicate these results. Community representatives along the coast have extensive experience in communications and are aware of what is relevant, thus they are a vital component of communication activities. Because this type of training had not been made available in Labrador to date, community representatives were at a disadvantage compared to other northern regions of Canada in dealing with these issues.

One of the recommendations made by key-informants in the NCP-funded research project, *Country Food Nutrition and Health: Developing Effective Communication Strategies in Labrador* (Lampe et al. 2000), states that organizations responsible for dissemination of information must support communication activities through training and open, active, internal communication networks. A regional and inter-community communications network should be developed for information exchange and communications capacity enhancement.

Activities 2000-2001

The LIA Research Office delivered a 3-day workshop in Nain, Labrador, for the staff of LIA and its affiliates who are responsible for communicating health, environment and contaminant issues and results of related research projects in the region.

LIA Research staff revised a draft copy of the Frontline Training Course manual (Farrow 2000) developed by Judy Farrow, Métis Nation-Northwest Territories, Environment Division, with guidance and assistance from C. Furgal, Research Associate, Public Health Research Unit, Laval University Hospital Centre. This revision was adapted to suit the needs of community representatives who are responsible for communicating environmental issues in northern Labrador.

Affiliates and staff of the LIA were informed in December 2000 that the course would be taking place in March 2001 and were asked to determine who would be representing their organization. Once the participants list was finalized, one representative from each affiliate was asked to provide feedback on the course agenda by indicating if the course material was relevant to their work. All questionnaires were returned with helpful comments.

Once the revision of the course material was complete, the course package was compiled and included the course agenda, objectives and conclusions with summary questions and answers for each day of the course, course handouts and research guidelines for the Labrador Inuit Settlement Area.

LIA Research staff were responsible for all logistical arrangements which included travel and accommodations for participants, arranging a meeting place and providing nutrition breaks during the course.

Results and Discussion

The Frontline Training Course for Community Representatives in Labrador was held in Nain, Labrador from March 6-8, 2001. There were 14 participants from the five north coast communities of Labrador representing the LIA, the Labrador Inuit Health Commission, the community of Makkovik, Town Council of Nain, and the OKalaKatiget Society, the regional communications center based in Nain. Other invited participants, such as representatives from Fisheries Guardians and Public Health were not available because of other commitments.

All of the course objectives (become familiar with contaminant issues in Northern Canada; learn ways of interpreting and communicating contaminants information; look at research methods; empower decision-making at the personal and community level; compile a list of Labrador resources utilized in the north coast communities) were met by participants. Topics covered during the course included: contaminants, introduction to the NCP, northern nutrition, LIA Research communication guidelines, recent research on contaminants and benefits of wild foods in northern Labrador, and scientific research/proposals.

Overall, the course was highly successful in achieving its goal of providing baseline information to community representatives responsible for the communication of health, environment and contaminant issues in northern Labrador. Course evaluation results show that participants found the information valuable, important and interesting, and that the delivery was highly effective. Because the course was delivered in a plain language format, the level of comprehension and retention was high. Participants returned to their communities feeling informed and pleased with the positive research results on the benefits of traditional/country foods in northern Labrador. There was interest in having the course offered again in other north coast communities so other community representatives could benefit from the information. The evaluation form completed by participants at the conclusion of the course is summarized in Table 1.

Conclusions

The front line training course can be considered successful in meeting its goals and enhancing the capacity of community workers and individuals in dealing with contaminant issues in northern Labrador communities. The experience of the instructor combined with the plain language format of delivery ensured a high level of comprehension and retention among participants.

This course also proved to be an effective two-way exchange of information. Not only did participants gain basic knowledge on contaminants in the environment and the benefits of traditional/country foods, but they also expressed the concerns of their communities and were able to have questions addressed by the knowledgeable instructor, presenters, and local researchers represented by LIA Research staff.

Project Completion Date

This project is now completed. LIA Research staff will ensure that the revised course manual is made available to organizations on the north coast of Labrador who have an interest in offering training to other community representatives and to the NCP Secretariat.

Acknowledgments

LIA Research staff would like to thank C. Furgal for his invaluable assistance and guidance throughout the project, from the first stage of revising the course manual to the final stage of instructing the course. The plain language presentations by D. Muir (POPs and Heavy Metals in Country Food and People) and E. Loring (CINE Dietary Study) introduced participants to new research results conducted in the region. Without the participation and interest of community representatives from the north coast communities of Labrador this course would not have been a success.

Table 1. Summary of course evaluations, Frontline Training Course for community representatives in Labrador

Query	Rating 1- Poor to 5- Excellent	Comments
General impression of course	4.3	• "Very well-prepared, fairly easy information to comprehend." • "I have attended previous workshops on contaminants in the past and this was by far the most interesting, informative and knowledgeable." • "Great presenters, good participants." • "I enjoyed the workshop and I learned a lot from it. Quite interesting, especially describing foods that we eat!"
Course content	4.5	• "But is there any more information people need to know?" • "Very organized and well prepared, information complete."
Organization of course material	4.6	
Overall rating of instructor	4.4	• "Easy going good to mix humour and laugh."
Value of course	4.4	• "Learned a lot of new things, met contacts and places to find more information."
Any topics omitted ?		• "Other contaminants that could have an influence on the health of the Inuit."
Any topics that needed elaboration?		• "More emphasis should be spent on the diet-CINE part of the presentation." • "More information on fish, i.e. parasites, PSP, etc." • "Diet and traditional food results from CINE study. Spend more time on 24-hour recalls." • "Local contaminant issues: How we can work towards eliminating or controlling local waste management habits."
Other community members who could benefit from this course		• Fishermen, fish-plant workers • LIA, LIA fieldworkers, people who can pass the information on and be advocates for traditional food consumption • Hunters • Wildlife technicians • Elders • Youth, children • Teachers • LIHC: Team leader, community health worker, public health nurse, clinic staff • Women's Group • Young mothers • Store managers
List five words to describe your learning experience		• Interesting, informative, objective, direct, honest • Good learning experience, relaxed-not rushed, fun, good facilitators/organizers, got good ideas from other communities to relate or relay messages to general public • Educational, alert, confidence • Informative, learning, interacting, research. • New knowledge, alarm, calmed down, Should I continue eating traditional foods? Assured again that it is SAFE, calmed, thankful • Positive, interactive, simple, understandable, fun • Interesting, informative, understandable, useful, excellent • Good, interesting, open mind, honest, truthful

Table 1 continued

Table 1. Summary of course evaluations, Frontline Training Course for community representatives in Labrador

Query	Rating 1- Poor to 5- Excellent	Comments
Suggestions to improve the course		Length: • Longer Participants: • Have Elders come in and give certain topics • More communities • More key people from the communities Content: • Not too many graphs • Concentrate a lot more on the positive and how that message can be delivered to the public and be well received. • More activity (i.e. smaller group/presentation)
General Comments		• "Continue with workshop like this one and give updates." • "It was a very good workshop the activities were very helpful. The group was very easy to get along with, and everything went smoothly." • "Everyone I think participated, but a few people present seem to be just absorbing the information brought forward, maybe because it's their first time participating in a format like this." • "Great course! I also like that there's a manual and other resources that we can take back to our communities." • "Thanks to the organizers and presenters for their job well done." • "Couldn't have done a better job ourselves!" • "It's information that should reach everyone."

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Abstract

The Northern Contaminants Program's (NCP) goal is to reduce and, wherever possible, eliminate contaminants in traditional/country food. Supporting this goal are the NCP's priorities for providing people with the tools and information for making their own informed decisions, through education, communication, and community participation in the program. One of the ways the NCP helps in reaching this goal is through training people to become Regional Contaminants Coordinators (RCCs) in each of the northern regions. In Labrador, the RCC's duties include acting as a liaison between five north coast communities and Upper Lake Melville, acting as a liaison for researchers, communicating research results and benefits of traditional/country foods in plain language through various mediums, assisting in the delivery of workshops, open houses, and information sessions, and carrying out projects funded by the NCP. In 2000-2001, the Labrador RCC took part in an RCC training course, delivered a Frontline Training course, produced and distributed a newsletter, liaised with and assisted researchers on projects such as Climate Change and Public Health in Nunavik and the Labrador PCB clean-up initiative at Saglek Bay, and continued with various other communication activities.

Key Project Messages

1. This project has enhanced the ability of the Labrador Inuit Association (LIA) Research Office to better understand the issue of human-made chemicals entering the environment, which is a cause for concern for Labrador Inuit, and to communicate information on contaminants, the environment and research that is in plain language, translated, and in an appropriate format for Labrador Inuit to use to make informed decisions about their health and environment.
2. The LIA Research Office strives to conduct research in a culturally relevant manner and promote mutually beneficial relationships between the communities of northern Labrador and outside researchers and scientists.

Objectives

The Regional Contaminants Coordinator (RCC), under the LIA Research Office, will continue to:

1. Provide information to assist and support residents of Nain, Hopedale, Postville, Makkovik, Rigolet and Happy Valley-Goose Bay in making informed decisions about risks related to contaminants in traditional/ country foods, the means to reduce risks, and information on the benefits of traditionally harvested foods.
2. Assist communities of the north coast of Labrador and Lake Melville in becoming involved with contaminant issues that affect the region and making informed decisions about their food use.
3. Act as a liaison with outside researchers conducting work in the region on these issues, supporting their work, and aiding them in conducting ethical, effective investigations and communicating these results to regional residents.

Introduction

Labrador Inuit are sustained by the animals, birds and fish of the region. Research has shown that contaminants are present in these food sources due to contamination of the environment through short-range and long-range atmospheric pollution. Labrador Inuit are concerned about the presence of these contaminants in their food sources and in the environment. Key concerns in Labrador include the PCB contamination at Saglek, where the United States Air Force constructed a Polevault communications station in the 1950s, and questions about the health of the George River caribou herd. In addition, Labrador Inuit are in the final stages of negotiating a land claim agreement and face many environmental health issues unique to this region and the Canadian North.

In accordance with the objectives of the Northern Contaminants Program (NCP), and as requested by key-informants in the NCP project *Country Food, Nutrition and Health: Developing Effective Communication Strategies in Labrador* (Lampe et al. 2000), the Labrador RCC duties are shared by Mary Denniston and Frances Murphy. They act as key resource people and provides Labrador Inuit Inuit with contaminants-related information that is culturally relevant and in a plain language format. The relationship between Labrador Inuit and outside researchers has, in the past, lacked consultation, understanding of the Inuit culture and proper communication procedures. Improvements have been made, however the need is ongoing for an RCC to assist in the establishment of mutually beneficial relationships among individuals, communities, and outside researchers.

Activities 2000-2001

Training

The Labrador RCC participated in the RCC training course that was delivered by the Inuit Tapirisat of Canada (ITC) in Ottawa, March 21-23, 2001. Judy Farrow, of Environmental Education Consulting in Yellowknife, Northwest Territories (NWT), was the instructor for the training course and also developed the course manual. During the training course, RCCs met for the first time and got to know each other. Participants developed forms that could be used to communicate information to the Labrador Inuit Association and others as well as strategies for organizing workshops and information sessions. Procedures for writing proposals, using the NCP blueprints, and budget information (what funding is available, using it productively, other funding sources) were reviewed and licensing requirements for Nunavut and the NWT were discussed. A draft license package has been developed by LIA Research for Labrador.

Communication

Frontline Training course for community representatives in northern Labrador

LIA Research staff, Mary Denniston and Frances Murphy, delivered this training course in March 2001, with Chris Furgal acting as the facilitator/instructor. The course was developed to educate frontline workers about contaminants and the benefits and risks of traditional/country foods, and to help them to understand how the different types of contaminants enter into the food chain and how they pass into the environment. The course manual was developed by the Métis Nation-Northwest Territories, but was not directly appropriate for the Labrador region. Therefore LIA Research staff and C. Furgal revised the manual to make it both culturally and technically relevant for the people of the Labrador region; the Labrador version of the manual now exists in an electronic format. In total, 14 participants from five communities along the coast of Labrador, including Nain, participated in the course. These participants included public health aides, community health workers, LIA fieldworkers, hunters, fishers and students.

Eric Loring of the ITC and Derek Muir of the National Water Research Institute also attended the training course. E. Loring gave an introduction to the Centre for Indigenous Peoples' Nutrition and Environment (CINE) dietary study (Kuhnlein et al. 2000), and D. Muir gave a presentation on the work he has done on contaminants in animals in different northern regions, including Labrador.

Avativut newsletter

This newsletter is a quarterly newsletter that the LIA Research Office has developed as a tool to communicate to the Labrador Inuit about the benefits and risks of traditional/country foods, contaminants, health and environmental issues in this region. The RCC has enhanced the LIA Research Office's ability to communicate such information in a culturally relevant manner. The main focus of the Avativut newsletter is on the benefits of traditional/country foods, to stress that traditional/country foods are still the most nutritious foods to eat. Additional updates of new and ongoing research activities and relevant facts about health and environment issues in the region are also provided in this newsletter; English and Inuktitut (Labrador Dialect) versions are produced and distributed four times a year.

PCB clean-up at Saglek, Labrador

The RCC has assisted with incorporating the communication channels utilized by the Environmental Sciences Group, Royal Military College, Kingston, Ontario, and the Department of National Defense on issues of the presence of PCB contamination in the Saglek Bay area. The communication channels utilized this year were suggested by the RCC and were requested by key-informants during the NCP project *Country Food, Nutrition and Health: Developing Effective Communication Strategies in Labrador previously* (Lampe et al. 2000).

The information being communicated to date includes information on the marine and terrestrial plants and animals that may have come into contact with PCBs, the effects this may have on people, and communication of up-to-date information on the clean-up activities of the contaminated soil at the site.

Youth symposium

LIA Research staff were invited to give a presentation at the 8th Annual Youth Symposium on April 26, 2001, in Makkovik, Labrador. This symposium gives Labrador Inuit youth a chance to receive an update on LIA and its affiliates, and to discuss issues facing Labrador Inuit youth today. The presentation introduced delegates to the role of the LIA Research staff and the RCC, the various benefits of traditional/country foods, and the CINE video, *Careers in Nutrition and the Environment*, to spark possible interest in careers they may choose to seek.

Liaising/Contact

Climate change and public health in Nunavik and Labrador

C. Furgal, of Quebec University Hospital Centre (CHUQ), is conducting research on the impacts of changes in the environment and climate in Northern Labrador and Nunavik. LIA Research staff, M. Denniston and F. Murphy, are assisting him in gathering knowledge from local Elders and hunters. This includes getting people together in focus groups to discuss their knowledge of the changes in the environment and weather, and the impacts it has had on the people with regard to the plants they gather and animals they eat, as well as conducting interviews with individuals on their knowledge of these changes and impacts.

Ongoing daily communications and research coordination

Daily activities of the Research Office involve responding to community concerns, providing information to the LIA, communities and individuals on issues relating to contaminants, the environment and health, and acting as a liaison for the various people proposing to and conducting work in the region. Additionally, the RCC acts as liaison for interactions between the region and ITC and the NCP.

Results

This project has enabled and enhanced the abilities of the LIA Research Office to continue its mandate of providing information on contaminants, research and the environment, acting as a liaison between communities and outside researchers, conducting research and acting as a co-facilitator in delivering workshops and training for community representatives. This project has also enabled the RCC to improve the way information is being presented and delivered to Inuit communities of northern Labrador by utilizing the latest project results for the region in developing effective communication strategies funded by the NCP. In addition to facilitating communications on contaminants information, this project has enabled the RCC to anticipate and reduce the possibility of misunderstandings and mistrust among communities, organizations, researchers, and scientists.

Discussion and Conclusions

The RCC has been a valuable addition to the LIA Research Office. The training that was offered to RCCs in March 2001 enhanced the abilities of the RCC to educate and empower the people of Labrador to better understand and deal with contaminants in their environment and traditional/country foods, research and other environmental issues.

Specifically, the addition of a RCC has:

- Enhanced the initiative taken by LIA Research Staff in providing information on research of contaminants, their effects on traditional/country food and the environment according to the varied language and geographic needs of individuals and communities of Labrador.

- Enhanced decision making of Labrador Inuit because information on risks and benefits, relevant to the region, are now made available in an accurate, timely, and accessible manner.
- Enabled the RCC to continue to develop regionally relevant resource materials in consultation with the coastal communities and appropriate agencies (i.e. The Labrador Inuit Health Commission, Department of Indian Affairs and Northern Development, etc.). These materials include educational materials, such as posters and a quarterly newsletter, with a mandatory requirement of being available in Inuktitut and English.
- Made use of the research results from studies conducted in the region (e.g. Lampe et al. 2000), to aid in effective delivery of information.
- Assisted outside researchers with community consultations. This assistance also includes negotiating research agreements and reporting project results to communities. The RCC determines, in consultation with community representatives who are responsible for communication of contaminants and health and environment related issues, which medium(s) best suit the information needs of the community. These include presentations and workshops delivered in a plain language format. The RCC continues to assist communities in identifying and prioritizing contaminants issues and continues to assist in communicating community concerns and priorities to the appropriate authorities.

Expected Project Completion Date

This project is ongoing.

Acknowledgments

The LIA Research staff would like to thank C. Furgal, Research Associate, CHUQ Research Centre, for his invaluable assistance and support in carrying out projects funded under the NCP. Also, E. Loring, Environment/ Wildlife Co-ordinator, Inuit Tapirisat of Canada, for his involvement and guidance with the RCC position. The support of the LIA's executive and its delegates ensures the continuation of the LIA Research Office mandate. We would also like to give special thanks to John Jararuse, Interpreter/Translator, LIA, for the translation of communication materials.

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Qikiqtani Inuit Association Regional Contaminant Coordinator: a Five-Year Strategy of Communication and Action on Contaminant Issues in the Canadian Arctic

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Abstract

The Inuit of Qikiqtaaluk rely heavily on traditional/country food as a critical component of their diet, economy and social practices. Due to concerns among Inuit communities regarding contaminants in the food chain, a Regional Contaminants Coordinator (RCC) position was established by the Inuit Tapirisat of Canada (ITC) for the Qikiqtaaluk (Baffin) region. The RCC is essential in providing a regional voice for the Northern Contaminants Program (NCP) as well as providing the communities in this region with a "familiar" person to go to with questions and concerns – someone who can speak their own language and shares the same concerns. During the year 2000-2001, the RCC was involved in an orientation program in Ottawa at the offices of ITC. Here, planning began for a tour of five Qikiqtaaluk communities to bring back contaminant information collected in their communities, to address concerns and to provide information related to contaminant concerns. The RCC attended workshops in Ottawa and Winnipeg, an RCC training session in Ottawa, and participated in all Nunavut Environment Contaminant Committee meetings.

Key Project Messages

1. The communities within the Qikiqtaaluk (Baffin) region have a broad range of concerns related to contaminants and their effects on wildlife and human health and it is important that there be an ongoing, coordinated exchange of information and research results

between researchers and project managers and community members.

2. The Qikiqtani Inuit Association (QIA) Lands Department strives, in a culturally relevant manner, to continue its communication efforts on contaminants research and the environment, conduct research and promote mutually beneficial relationships between the communities of Qikiqtaaluk and outside researchers and scientists.
3. This project has enabled the QIA Lands Department to continue these communications, research and liaison activities, in order to effectively communicate information on contaminants in the food chain and the environment, enabling Inuit in Baffin to make informed decisions.

Objectives

The objectives for the QIA Regional Contaminants Coordinator (RCC) include:

1. Achieve an appropriate level of understanding about contaminants among Inuit.
2. Achieve a level of understanding about the concerns and questions that Inuit have in relation contaminant issues.
3. Provide a forum for responding to and facilitating interactions within and between communities with regard to contaminant issues, and to facilitate the link between communities, the Northern Contaminants Program (NCP), and NCP scientists.
4. Communicate up-to-date, understandable information about contaminants to Inuit in the Qikiqtaaluk region.
5. Build capacity in as many Inuit communities as possible, to effectively communicate community concerns and priorities with regards to contaminants to other decision-making bodies at the regional, national and international levels.
6. Mobilize, build and enhance partnership among community members, regional organizations and the scientific community.

Introduction

The NCP recognized the need and value of RCCs and provided the Inuit Tapirisat of Canada (ITC) with funding for RCCs in all of the Inuit regions. The RCC from the Qikiqtani Region, Salome Qaunaq, worked with ITC and acted as a conduit for two-way information exchange between the communities of Kimmirut, Iqaluit, Kinngait (Cape Dorset) Pangnirtung, Sanirajaq (Hall Beach), Igloolik, Qikiqtarjuaq (Broughton Island), Kangiqtugaapik (Clyde River), Mittimatalik (Pond Inlet), Ikpiarjuk (Arctic Bay), Qausuittuq (Resolute Bay), Ausuittuq (Grise Fjord) and Sanikiluaq and ITC, and ultimately with the NCP. This was done by delivering timely, accessible (layman language, local dialects, etc.), accurate and detailed contaminant information to a broad spectrum of community members.

The QIA RCC also responded to local information requirements about contaminants (using, as necessary, contacts at national Aboriginal organizations, Northwest Territories Environmental Contaminants Committee, Nunavut Environmental Contaminants Committee [NECC], federal government organizations, such as the Department of Indian Affairs and Northern Development (DIAND) and Health Canada, NCP scientists, etc.). Responsibilities also included facilitating the communication of community concerns and priorities to the appropriate levels and ensuring that relevant regional and community organizations were kept informed and that their input was brought back to NCP.

Activities in 2000-2001

To learn about the RCC position, the QIA RCC, Salome Qaunuq, worked in Ottawa under the guidance of Eric Loring at ITC. During this week of training, the RCC prepared for the Eastern Arctic Tour, which took place in January 2001, by learning about the NCP and issues that affect the Inuit of Canada, and by calling communities and introducing herself. Proposals for the 2001-2002 year were also developed. In February, the RCC attended the Human Health and Contaminants Workshop and Country Food Monitoring Workshop hosted by the NCP and Health Canada respectively in Ottawa, Ontario.

The Eastern Arctic Tour, coordinated by the QIA RCC, visited the communities of Cape Dorset, Coral Harbour and Hall Beach; unfortunately weather kept the tour from reaching Arctic Bay. Members of the tour included Glen Stephens (DIAND), Eric Loring (ITC), Derek Muir (Environment Canada) and Dr. Anne Roberts, chief medical officer of Nunavut. The RCC was responsible for introducing the group, answering questions, translating, getting equipment and making necessary arrangements. The two-way information exchange between the communities and members of the tour was beneficial. For instance, although people were already aware of contaminants in the environment and climate change, presentations about the grasshopper effect and community studies by Derek Muir, from Environment Canada, were very useful to them. The tour also allowed the QIA RCC to meet community contacts and listen to community concerns.

Other activities included:

- RCC training in Ottawa, in which the QIA RCC met with Inuit representatives from the other six regions and made valuable links to communication efforts and shared education ideas in relation to contaminants.
- Orientation in Ottawa, with ITC, which provided the QIA RCC with an opportunity to see what the national Inuit organization was doing about the issue of contaminants, the hurdles that they faced and the obstacles that they overcame. It also provided the RCC with an opportunity to meet in person with the people whom she would hear on the phone over the upcoming months.
- Participating on the NECC.
- Review of NCP proposals.
- Writing the Northern Contaminants Project 2001-2002 Proposal for the RCC position for Qikiqtani.
- Eastern Arctic Contaminants Tour, which the QIA RCC organized, planned and facilitated.
- Participating in Nunavut Water Rights sessions in Toronto, Ontario
- Exchanging projects ideas with other RCCs.

Results

The role of the RCC in Qikiqtani is to bridge the gap between community members and NCP scientists and management. Local concerns focus on local sources of contamination and although these do not fall within the NCP's mandate, it is important to be able to address some of these non-NCP concerns in order to build trust and respect between community members and scientists. The RCC felt that in order to communicate NCP information, Inuit must first be aware of the big picture in their region, in particular, who is responsible for specific local issues of water or waste management and what is being done about them. Therefore, in order to be effective, RCCs must be concerned with issues both within and outside of the NCP's mandate.

Discussion and Conclusions

Since the RCC was appointed in November 2000, the QIA RCC has attended workshops and completed a training course that has helped in understanding the position and associated responsibilities. It is recommended that support for the QIA RCC for the Baffin Region be continued for as long as the people of Baffin Region have comments and concerns regarding contaminants.

The RCC has gained much knowledge relating to pollutants and contaminants, and the environment in general and has attempted to communicate this information to people in the community and surrounding regions. With more time and opportunities, more locally relevant information could be disseminated to the regional beneficiaries and the general public.

Expected Project Completion Date

This project is ongoing.

Eastern Arctic Contaminants Tour II

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Abstract

Building on the success of Eastern Arctic Contaminants Tour in 2000, a team consisting of a program representative, an Aboriginal partner, a health specialist and a scientist visited three communities in Nunavut in February 2001 to conduct information sessions on contaminants. Sessions held at both the local school and for the general public in each community included discussions on the following topics: where contaminants come from; contaminants in the ecosystem and food chain; contaminants and human health; ongoing activities; and other concerns that members of the community had in relation to contaminants, wildlife, waste and health issues. A good two-way dialogue was established, which helped everyone understand the issues and concerns. Unfortunately, scheduling problems postponed a tour for the Kivalliq region; it will be rescheduled for fall 2001.

Key Project Message

- The use of community tours appears to be an effective way of presenting contaminant-related information to a variety of audiences.

Objectives

1. Communicate the goals, objectives and priorities of the Northern Contaminants Program (NCP) Phase II to Inuit communities in the Baffin and Kivalliq regions.
2. Outline recent and current contaminant projects in the region and relay the findings of NCP Phase I.
3. Identify the issues and concerns of communities in Nunavut with regards to contaminants in the environment that could lead toward the development of a Nunavut monitoring plan.
4. Assist individuals and communities in making informed decisions about their use of traditional/ country foods.
5. Provide an education opportunity for local high schools and seek their involvement in the NCP.

Introduction

The traditional workshop approach used to convey research results and program information has involved bringing selected community representatives to a central location, providing them with information regarding contaminants and the NCP, and then sending them home. It had been the hope that these representatives would spread the information to the rest of the community. Realistically, this was an unfair burden to place on the community representatives; most of them were not in a position to talk to every interested person, nor was it usually their job to do so. Information overload and the potential for misinterpretation of the results and information was also a potential problem.

An alternative method for delivering the contaminant and NCP-related information is to send a small knowledgeable team to a community for a variety of meetings. This option was used in 1999-2000 and was found to be effective. The teams would generally consist of a program representative, an Aboriginal partner, a health specialist and a scientist. While the primary means of communication would be a public meeting, the team would also take advantage of the time in the community to talk with high school science classes, the Hunters and Trappers Association, the hamlet council and any other interested groups.

The advantages of going to a community, rather than bringing a single representative to an outside meeting, are numerous. Not only can more individuals be reached, but they hear the message from the source rather than second hand, and the team is able to answer most questions immediately. By having the team in the community and having more than just one public meeting, individuals have the opportunity to hear and comment about contaminants more than once. Also, because individuals are with their families and neighbours, they feel more comfortable expressing opinions and concerns about the program and contaminant issues.

Another benefit is the relationship-building that goes on while in the community. By having scientists go to the community, community members have an opportunity to meet some of the individuals (i.e. scientists, Aboriginal organization representatives, regional contaminant coordinators [RCCs]) who are working in their region. The benefits of improved relations between scientists and community members have been seen in proposals by scientists who have participated on community tours. Their communication before and after their research is excellent and their proposals usually address a concern from the community and involve local help.

A lesser benefit, but one that should be considered, is the economic benefit to the community. While in the community, the team inputs money into the local economy through accommodations and meals, logistical support (e.g. meeting organizer, translation services, hall rental) and souvenir shopping.

Activities in 2000-2001

The primary activity in 2000-2001 was the organization and delivery of the community meetings in the eastern Arctic in February 2000. Unfortunately, only three (Kinngait, Salliq and Sanirajaq) of the planned eight communities were visited. Unfortunately, visits to Ikpiarjuk, Arviat, Tikirarjuaq, Kangigliniq and Igluligaarjuk had to be cancelled due to inclement weather and unavoidable scheduling circumstances.

In each community visited this year, the team met with high school students in the afternoon and hosted a public session in the evening at the community hall. During spare time, the team would divide up and visit community health facilities, Hunters and Trappers Organizations, and local hamlet councils to explain to these "frontline workers" the reason for the visit and to introduce themselves.

Results

Eight communities were contacted to seek their interest in hosting and receiving a contaminants community visit and all responded positively. Although plans and arrangements were made well in advance, circumstances changed along with the weather and only three of the communities were visited. The format developed in 1999-2000 for the meetings was used and refined slightly for this year's meetings. The increased emphasis on advertising (radio announcements, flyers, door prizes) helped to attract larger audiences. The door prizes were a particular attraction, drawing over 30 people per workshop. High school visits have been identified by RCCs and by participants in the 1999 Eastern Arctic Contaminants Tour (Mills and Loring 2000) as important means by which to reach the youth audience; consequently arrangements were made to visit them in each community. Visits to the school were all very positive. They provided students with the opportunity to talk to professional scientists and health care workers, provided local role models through the RCC, and provided community members with actual hands-on involvement in viewing and editing the Inuit Tapirisat of Canada contaminant Web site via a private Internet access. A trip report has been prepared, which describes each meeting, and is available through the Nunavut Environmental Contaminants Committee in Iqaluit.

Discussion and Conclusions

The Eastern Arctic Contaminants Tour is evolving, learning each year how best to communicate the issue of environmental contaminants. This year's efforts were the most successful of all of the "tours" to date. The meetings were well attended (mostly due to the door prizes) and the large audiences had a variety of concerns, ranging from community health problems, to wildlife issues, to local contaminants problems. During each meeting, there was good two-way dialogue, which helped everyone understand the issues and concerns. Also, notifying the high schools with a few months notice enabled the teachers to prepare the students for the visits.

Future tours will continue to improve as they benefit from the lessons learned on this and previous tours. Two areas that should be considered in the future are the paucity of 30- to 45-year-olds attending the community meetings and an evaluation of the communication efforts.

Project Completion Date

This project was completed. Planning is underway for a tour in 2001-2002, likely in the Kivalliq region during the fall 2001.

References

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Kivalliq Inuit Association Regional Contaminants Coordinator: a Five-Year Strategy of Communication and Action on Contaminant Issues in the Canadian Arctic

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Abstract

There is a history of miscommunication regarding contaminants issues in Inuit communities; such instances have led to degrees of alarm, apprehension and mistrust. Major obstacles to effective communications have been language and cultural barriers. With the introduction of the Regional Contaminants Coordinators (RCCs), this apprehension, mistrust and alarm have been somewhat mitigated; now someone from the region can explain to community residents, in plain language, about contaminants. Promising communication strategies have been developed at the community level and the cross-pollination of ideas has occurred, at least informally, at the regional and inter-regional levels.

Key Project Message

- The communities of Kivalliq have a broad range of concerns related to contaminants and their effects on wildlife and the people who consume these animals. The presence of a local individual who can deliver messages about contaminants has helped ease tensions within the region and defuse potential mistrust and misunderstanding between communities and scientists working on contaminant issues.

Objectives

1. Achieve a level of understanding among Inuit in Kivalliq about contaminants.

2. Understand the concerns and questions that Inuit have in relation to contaminant issues and to effectively communicate community concerns and priorities, with regards to contaminants, to other decision-making bodies at regional, national and international levels.
3. Provide a forum for responding to and facilitating interactions within and among communities with regard to contaminant issues.
4. Build capacity at the community level, in as many Inuit communities as possible, and to communicate up-to-date, understandable information about contaminants.
5. Mobilize, build and enhance partnership among community members, regional organizations and the scientific community.

Introduction

The Kivalliq Regional Contaminants Coordinator (RCC) position was a product of the Eastern Arctic Contaminant Workshop in Iqaluit in 1998. Prior to April 1999, no RCCs existed in Nunavut or eastern Northwest Territories to communicate scientific results regarding contaminants or contaminants in general to communities. Through RCCs, it was hoped that contaminant information would be communicated more easily to communities and that a better understanding of this issue would develop.

Recognizing the need and value of RCCs, the Northern Contaminants Program (NCP) provided the Inuit Tapirisat of Cananda (ITC) with the funding for RCCs in all of the Inuit regions. The Kivalliq Inuit Association established an RCC position in September of 2000.

Activities in 2000-2001

Contaminants action plans have been developed in four Inuit regions (Inuvialuit, Nunavik, Nunavut and Labrador) and RCCs have been established in each.

The RCC from the Kivalliq Region, Eric Ukpatiku, working with ITC, acted as a conduit for two-way information exchange between the communities of Arviat, Kangigliniq (Rankin Inlet), Tikirarjuaq (Whale Cove), Igluligaarjuk (Chesterfield Inlet), Qamanittuaq (Baker Lake) Salliq (Coral Harbour) and Naujaat (Repulse Bay). The RCC facilitated the delivery of timely, accessible (plain language, local dialects, etc.) accurate and detailed contaminant information to a broad spectrum of community members.

The RCC has been involved in several initiatives throughout the year, including planning upcoming community tours and participating in all Nunavut Environmental Contaminants Committee meetings, the annual NCP results workshop, the NCP workshop (Contaminants and Human Health in the Canadian Arctic: an Update), and the Health Canada workshop (Country Food Monitoring).

The Kivalliq RCC also responded to local information requirements about contaminants – using, as necessary, contacts at national Aboriginal organizations, the Northwest Territories Environmental Contaminants Committee, Nunavut Environmental Contaminants Committee, federal government departments such as the Department of Indian Affairs and Northern Development and Health Canada, NCP scientists, etc. Responsibilities also included facilitating the communication of community concerns and priorities to the appropriate levels, ensuring that relevant regional and community organizations were kept informed, and ensuring that their input was brought back to NCP.

Results and Discussion

The role of the Kivalliq RCC is to bridge communication gaps between community members and NCP scientists and management. Local concerns most often focus on local sources of contamination, which do not fall into the NCP mandate. Therefore, the RCC also looks to answer these concerns and to educate community members about different sources of pollution. This helps in building trust and respect; therefore, it is important to be able to address some of these non-NCP concerns. The RCC felt that to communicate NCP information, he must first be aware of the big picture in his region, in particular, who is responsible for specific local issues of water or waste management and what is being done about them. Therefore, in order to be effective, RCCs must be concerned with issues both within and outside of the NCP mandate.

In the upcoming year (2002-2002), the RCC will be involved in delivering data from the Centre for Indigenous Peoples' Nutrition and Environment dietary study (Kuhnlein et al. 2000). A workshop and community tour are planned for the fall of 2001.

Conclusions

Thus far, the Kivalliq RCC has learned a considerable amount about pollutants and contaminants, and the environment in general. He has attempted to communicate this new knowledge to other people in the community and the region. With more time and opportunity, more locally relevant information can be disseminated to the regional beneficiaries and the general public.

Expected Project Completion Date

This project is ongoing.

References

Kuhnlein, H.V., O. Receveur, H.M. Chan and E. Loring. 2000. *Assessment of Dietary Benefit/Risk in Inuit Communities*. Ste-Anne-de-Bellevue, QC: Centre for Indigenous Peoples' Nutrition and Environment. ISBN # 0-7717-0558-1.

International Policy

Canadian Arctic Indigenous Peoples Against Persistent Organic Pollutants: Support for International Action

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Abstract

Four northern Aboriginal organizations – Inuit Tapirisat of Canada, Inuit Circumpolar Conference (ICC) Canada, Dene Nation and the Council of Yukon First Nations – have, as a coalition, participated in international negotiations to ban and/or phase out the use of key persistent organic pollutants (POPs) brought to the Arctic by wind currents where they bioaccumulate in the food web. Significant levels of POPs are found in Aboriginal people who eat large quantities of traditional/country food containing POPs. The involvement of the coalition has been well received nationally and internationally, and the recently concluded global POPs convention in Stockholm singles out the Arctic and Indigenous peoples. That it does so reflects the advocacy of the coalition, the Government of Canada and certain other Arctic nations attuned to Indigenous peoples. The coalition participated and intervened in all negotiations in Montreal, Nairobi, Geneva, Bonn and Johannesburg. Speeches delivered at these negotiations on behalf of Inuit and the coalition by Sheila Watt-Cloutier, President of ICC Canada, can be found on the ICC Canada Web site (inuitcircumpolar.com).

Key Project Messages

1. Northern Aboriginal peoples are able to influence global POPs negotiations.
2. The Government of Canada's substantive position and negotiating posture in global POPs discussions is markedly strengthened by working with northern Aboriginal peoples.
3. Arctic nations and Aboriginal peoples working co-operatively through the Arctic Council were able to significantly steer the agenda on the global POPs negotiations.

Objectives

1. To raise international awareness of the interests and concerns of Canadian Arctic Aboriginal peoples about transboundary contaminants.
2. To ensure Canadian Arctic Aboriginal peoples participate fully in domestic and international decision making about transboundary contaminants, particularly in international negotiations to ban and/or phase out the use of offending POPs.
3. To ensure that international agreements on POPs reflect the concerns and interests of Canadian Arctic Aboriginal peoples.
4. To ensure that the prospective global POPs convention is comprehensive, verifiable and rigorously implemented.

Introduction

The scientific research of the Northern Contaminants Program (NCP) and additional research programs have shown conclusively that various POPs released to the environment in tropical and temperate countries make their way to the Arctic where they bioaccumulate and biomagnify. Inuit and other Aboriginal peoples ingest POPs by eating certain traditional/country food, particularly marine mammal fats. It is of compelling importance that these peoples understand and appreciate not only the benefits of eating nutritious traditional/country foods, but also the health risks of ingesting POPs through these foods. The involvement in the NCP of the Dene Nation, Council of Yukon First Nations (CYFN), Inuit Tapirisat of Canada (ITC) and Inuit Circumpolar Conference (ICC) Canada helps to ensure that this is the case.

As Aboriginal peoples learned of the POPs issue, they expressed a strong desire to participate in the only sensible long-term policy option to address the problem – conclusion of international agreements to turn off the POPs taps at their source. In the spring of 1997, the Aboriginal peoples organizations formed the Canadian Northern Aboriginal Peoples Co-ordinating Committee on POPs, later to be named the Canadian Arctic Indigenous Peoples Against POPs (CAIPAP). In 1998, the coalition was joined by representation from the Russian Association of Indigenous Peoples of the North (RAIPON).

Aided by a part-time technical advisor, the coalition brought the concerns of Aboriginal peoples to the attention of the Canadian team negotiating the United Nations Economic Commission for Europe POPs protocol to the Convention on Long-range Transport of Atmospheric Pollution and, subsequently, the global POPs process sponsored by the United Nations Environment Programme (UNEP).

CAIPAP participates in meetings with the Canadian delegation to recommend positions and priorities that reflect Aboriginal and northern interests and concerns. As well, the coalition co-operates with selected environmental, public health and other non-governmental organizations in the international negotiations, including the International POPs Elimination Network, the Canadian Arctic Resources Committee, Physicians for Social Responsibility and the World Wildlife Fund. The coalition has also worked with the North American Council for Environmental Co-operation.

All members of the coalition use their membership in CAIPAP as a base for involvement in international aspects of the POPs issue. The position of the coalition, as outlined in an extensive and detailed position paper is to eliminate key POPs as soon as possible (see speeches delivered in the global POPs negotiations printed in ICC Canada's quarterly journal "Silarjualiriniq" and on the ICC Canada Web site: inuitcircumpolar.com). ICC Canada and ITC have also concentrated attention on the national and international media, and participated in the amendment of domestic legislation and policy including the *Pest Management Control Act* and the *Canadian Environmental Protection Act*. Interventions by ICC Canada on behalf of the coalition in the annual Parliamentary Ecosummit have also been used to press for action on POPs.

Activities in 2000-2001

The coalition participated in negotiations in Johannesburg in November and December 2000, and in the final conference of plenipotentiaries in Stockholm in May 2001. As well, the coalition participated in various meetings and briefing sessions organized by the Government of Canada to define its negotiating position and implementation strategy.

Discussion and Conclusions

The coalition has proven itself to be an effective vehicle to bring the concerns and positions of northern Aboriginal peoples to the attention of the Government of Canada and to nations around the globe. Not only the recently concluded global convention attests to this fact, but also the press releases issued by UNEP on the occasion of the signing of the convention, which featured the Arctic dimension to this global issue. The assistance of RAIPON was politically very helpful to the coalition.

In October 2000, two new international Indigenous peoples organizations – Gwich'in Council International and the

Arctic Athabaskan Council – joined ICC as "permanent participants" to the eight-nation Arctic Council. This was important to the POPs debate and the work of the coalition for it grounded the non-Inuit members of the coalition, both of whom are members of these new organizations, in circumpolar Arctic work, including that conducted by the Arctic Monitoring and Assessment Programme (AMAP). Importantly, the NCP and AMAP have collaborated for many years.

The ability of the coalition to work internationally reflected the excellent working relations established through the NCP – an unintended but very welcome outcome of the program – and the ability to call upon advice of the McGill University Centre for Indigenous Peoples' Nutrition and Environment. As well, good relations between the coalition and the Minister of the Environment and his political staff were also important. The Minister's press conference announcing Canada's signature and ratification of the convention featured political representatives of ICC Canada and CYFN.

The coalition developed a broad position on substantive issues which called for a global POPs convention to be comprehensive, verifiable and rigorously implemented. In particular, the coalition was wary of arrangements that would perpetuate management rather than elimination of POPs. Ensuring adequate funding to implement the convention, and promoting use of the Global Environment Facility to do so, was also a major concern. Translating the coalition's general position into language required significant technical work on a number of fronts including timetables for assumption of elimination obligations, trade restrictions, capacity building in developing countries and those with economies in transition, and monitoring and compliance provisions.

At the final negotiating session in Johannesburg the coalition met with Nelson Mandela, former President of South Africa, to enlist his support for the POPs convention. As well, Paul Okalik, Premier of the Government of Nunavut, joined the coalition in Johannesburg to lend his government's support to the coalition. At the signing in Stockholm, Sheila Watt-Cloutier was singled out by Klaus Topfer, Executive Director of UNEP, for an award recognizing the professional efforts of the coalition in the negotiations. This award accurately exemplified the work of the coalition.

With the signing of the POPs convention the work of the coalition comes to an effective end, although individual members continue to work in the NCP as well as in AMAP. The international POPs story and the NCP are closely linked. Indeed, a coherent case can be made that the global POPs convention is a singular, and perhaps rare, foreign policy success for the Government of Canada. That this success owes much to the scientific base provided by the NCP and the political support and public relations and advocacy work of the coalition is appreciated by those directly involved in the negotiations. To explain and publicize these links, ICC Canada is working with the Columbia University Centre for Science, Technology, and Environmental Policy to prepare and have published by McGill-Queen's University Press in 2002 a book on Canada's contribution to the POPs debate. The work of the coalition will also be featured in this book.

Project Completion Date

This project is completed.

Facilitation of International Action Related to Long-Range Transport of Contaminants into the Arctic

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Northern Contaminants Program Management Committee

Abstract

Persistent organic pollutants (POPs) from distant sources are transported mainly via the atmosphere to the Arctic where they accumulate in humans and in the Arctic food chain. The Northern Contaminants Program (NCP) supports the development of international controls on the use of these substances of concern. The support for these controls includes the following three initiatives: (1) the POPs protocol under the United Nations Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution, for which work is continuing to ensure compatibility of contaminant trends and survey activities under the NCP with trends and survey information gathering under the Convention; (2) facilitating negotiation of global actions on POPs, for which Canada has contributed $20 million for capacity building in developing countries in support of these negotiations; and, (3) cooperative actions under the Arctic Council, including contributing to the Arctic Monitoring and Assessment Programme (AMAP) which monitors the levels of, and assesses the effects of, anthropogenic pollutants in the circumpolar Arctic environment.

Key Project Messages

1. The United Nations Environment Programme Global Convention on Persistent Organic Pollutants (POPs) became available for signatures in June 2001. Canada was the first country to ratify the Convention.
2. An Expert Group has been established by the Convention on Long-Range Transboundary Air Pollution (LRTAP) to consider the possible addition of substances to the Aarhus POPs Protocol.
3. A global assessment of mercury has been initiated for completion by 2003.
4. The second Arctic Monitoring and Assessment Programme (AMAP) report will be completed in the autumn of 2002.

Objectives

1. Facilitate international cooperation to enable the identification of the significance of long-range contaminant sources outside of Canada and their transport pathways.
2. Develop and maintain appropriate international controls on emissions and discharges.

Introduction

Persistent organic pollutants (POPs) from distant sources are transported to the Arctic mainly via the atmosphere. They accumulate in humans and in the Arctic food chain and reach levels of concern in many traditional food species important to northern Aboriginal people. The Northern Contaminants Program (NCP) was established to define the significance of observed levels, to provide information to Northerners on possible dietary health implications, and to support the development of appropriate international controls on the substances of concern.

The reduction and elimination of contaminant input to the Arctic requires comprehensive international cooperation and includes the following elements:

- Maintaining the legally binding protocol on POPs negotiated under the LRTAP Convention to apply in the region of the United Nations Economic Commission for Europe (UN ECE). This region covers much of the Northern Hemisphere.
- Facilitating and negotiating global actions on POPs.
- Cooperative actions under the Arctic Council, including participating in:
  i) AMAP which monitors the levels of, and assesses the effects of, anthropogenic pollutants in the circumpolar Arctic environment; and
  ii) the Arctic Council Action Plan (ACAP) which is implementing pollution prevention activities to address Arctic pollution.

Activities in 2000-2001

UN ECE LRTAP Convention

The legally binding POPs Protocol, under the UN ECE LRTAP Convention, was signed by 34 countries (including Canada) at the UN ECE Ministerial Conference in Aarhus, Denmark in 1998. The agreement will come into force as a legally binding document for those countries that have ratified it when it has collected 16 ratifications. As of June 2001, six countries have ratified it. The agreement bans or severely restricts the manufacture, use or loss to the environment of initially 16 substances, including all POPs of concern in the Canadian Arctic. It also includes a mechanism allowing for the later addition of more substances. A similar protocol controls the manufacture, use or loss of the heavy metals cadmium, lead and mercury. Work activities in 2000-2001 relate to preparing to meet the obligations of the protocol once it has entered into force, with particular attention being paid to the procedure for adding new substances to the protocol.

Development of global action on POPs

In Montreal in June 1998, Canada hosted the first negotiating session to achieve global controls on POPs through a new Convention under the auspices of the United Nations Environment Programme (UNEP). The final (5th) negotiating session (INC-5) was concluded in December 2000 in Johannesburg, South Africa, and by August 2001 the Convention had been signed by more than 100 countries. In addition to controls on 12 identified POPs, several interesting features of the Convention include:

- the utilization of the Global Environment Facility as the interim mechanism to provide capacity building assistance to developing countries as they move to eliminate their use of POPs;
- a mechanism to add further POPs to the Convention; and
- the obligation to evaluate the effectiveness of the Convention, thus requiring the collection of information on the environmental levels of POPs.

Cooperative actions under the Arctic Council

AMAP

At the inaugural 1991 Rovaniemi Ministerial Conference under the Arctic Environmental Protection Strategy (AEPS), it was agreed to develop a monitoring and assessment program "*to monitor the levels of, and to assess the effects of anthropogenic pollutants in all relevant components of the Arctic environment*." The first AMAP assessment included considerable contributions from the NCP and was presented both at the June 1997, Alta, Norway AEPS Ministerial conference, and at the September 1998 Iqaluit Arctic Council Ministerial meeting. At Alta, Ministers provided guidance on future activities for AMAP. The key features relating to POPs, heavy metals, and radionuclides included: (1) increased emphasis on effects (including combined effects) and on human health implications; and (2) time trend studies at key locations. The next AMAP report will be delivered in 2002 and will focus upon these elements.

ACAP

In 1998, the Arctic Council decided to establish ACAP as a cooperative program to address some of the pollution issues identified in the 1997 and 1998 reports from AMAP. ACAP was formerly launched by the Arctic Council in October 2000 and the NCP is contributing to several of its activities.

Results and Discussion

UN ECE LRTAP Convention

The LRTAP Convention has established an expert group to assist in the examination of potential candidate substances for addition to the POPs Protocol. Canada is chairing the expert group and the NCP is providing key information on the presence of certain substances in remote areas as evidence for long-range atmospheric transport. Dossiers on five "new" substances are presently being examined. More information on the LRTAP Protocol on POPs and on the work of the experts group can be found at http://www.unece.org/env.

Development of global action on POPs

Moving the new Stockholm Convention on POPs into action will present a very difficult challenge for most developing countries where POPs are still heavily utilized. Canada announced at INC-4 a contribution of $20M (Canadian) for capacity building in support of the agreement.

The NCP contributed to the successful conclusion of the negotiations by:

- making available to the negotiators information on long-range transport of POPs and on exposure to wildlife and humans in the Arctic;
- supporting the Canadian Arctic Indigenous Peoples Against POPs (CAIPAP), which was very effective at explaining northern issues at the negotiations;
- developing the concept of a global POPs monitoring programme. This has been incorporated into the Convention as a tool to evaluate its effectiveness and the NCP represents a major portion of Canada's capacity to comply with this obligation; and
- supporting capacity building in developing countries in their programmes to move away from the use of POPs. Southeast Asia has been targeted since this region is believed to be a significant source of POPs emissions and discharges. In this period, a second training session on Integrated Pest Management was co-hosted with UNEP in Thailand.

More information on the POPs Convention under the UNEP can be found at http://www.unep.ch.

Cooperative actions under the Arctic Council

AMAP

Activities in 2000-2001 continued to focus on implementing the Canadian contribution to the second phase of AMAP and providing our share of the support to the AMAP infrastructure. In addition, the NCP, the Canadian International Development Agency and AMAP have cooperated to establish a POPs atmospheric monitoring facility at Amderma in Russia's western Arctic region. The station has an operation time frame of May 1999 to September 2001 for POPs analysis and utilizes identical equipment to that employed at Alert, Nunavut. In 2000, equipment needed to measure gaseous elemental mercury in ambient air was also installed at this station (using NCP funding). Mercury and POPs data from this air monitoring station will be available to NCP and AMAP scientists for inclusion in upcoming assessment reports.

The next major AMAP assessment will consist of a series of reports on individual topics (e.g. POPs, heavy metals, radionuclides, human health, etc). Recalling the presentation of the first AMAP report to the UN Commission on Sustainable Development in 1997, and the desire of Ministers expressed at Alta to bring the attention of the world to the state of pollution of the Arctic environment, this assessment will be completed in the autumn of 2002 before the World Summit on Sustainable Development in Johannesburg.

A "progress report" from AMAP was presented to ministers at their conference in Point Barrow, Alaska in October 2000. At this time, AMAP recommended that UNEP be requested to conduct a global assessment on mercury with a view to assessing the need for possible future global control actions. The Arctic Council made this request and UNEP Governing Council has requested that such a review be completed by early 2003.

More information on AMAP activities can be found at http://www.amap.no.

ACAP

In October 2000, Arctic Council Ministers launched ACAP and approved the conduct of seven projects. They include:

i) PCB phase out in western Russia – At the conclusion of negotiations of the LRTAP POPs Protocol, Russia stated that its dependence on PCBs for electrical transmission purposes precludes their commitment to a ban on production of these substances and that therefore they were unable to sign and ratify the agreement. In 1998, the NCP began contributing to an AMAP-led project to assist Russia with this issue, which has now evolved into the ACAP activity. The initial phase consisted of compiling an inventory of PCB use and stockpiles in western Russia, and this has now been completed. This provided the basis for the development of preventative and remedial action plans and identification and utilization of alternatives to PCBs. These form the primary elements of the second phase of the ACAP Project, which has now been initiated.

ii) Mercury emission reduction project – This is a similar project to the ACAP PCB initiative. It is not exclusively focussed on Russia, but since Russia was also unable to sign the 1998 Aarhus LRTAP Heavy Metals Protocol, particular attention is being given to assisting Russia. The first component consists of the development of an emission inventory. The NCP through AMAP is contributing to this work.

Conclusions

Work under the above initiatives is continuing.

Expected Project Completion Date

This project is ongoing.

Program Management

Northwest Territories Environmental Contaminants Committee

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◆ **Project Team:**

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Abstract

The Northwest Territories Environmental Contaminants Committee (NWTECC) membership is composed of representatives from various departments of the federal and territorial governments as well as national and regional Aboriginal partners. The Committee meets regularly throughout the year to facilitate scientific study and assessments, as well as the communication of information to Northerners on the presence and possible effects of contaminants in the environment. The NWTECC also facilitates the communication of northern priorities to researchers. The NWTECC met seven times in 2000-2001.

Key Project Messages

1. The Northwest Territories Environmental Contaminants Committee (NWTECC) enabled 16 different Aboriginal and government organizations in the NWT to coordinate their activities related to contaminants.
2. The NWTECC provided a forum for discussion and two-way transfer of contaminants-related information among Northerners of the Northwest Territories (NWT), researchers and programs such as the Northern Contaminants Program (NCP).

Objectives

1. Provide a forum for the two-way transfer of contaminants information among Northwest Territories (NWT) Northerners, researchers, the Northern Contaminants Program (NCP) and other contaminants-related programs.
2. Establish a communications network that ensures Northerners are informed and involved in contaminants-related activities.

3. Identify priorities and information gaps related to environmental contaminants research in the NWT.
4. Act as a central repository for environmental contaminants information.
5. Provide advice on appropriate funding sources.
6. Review NWT proposals for the NCP prior to full technical reviews.

Introduction

The NCP is mid-way through its second phase, with more than 10 years of research to date. The program has evolved to include NWT communities and regions extensively in research and communication efforts. This has increased the need to have a central body that can coordinate contaminants information and research initiatives. The NWTECC provides an opportunity for researchers and communities to provide input into contaminants activities and express their concerns.

Membership is composed of representatives from various departments of the federal and territorial governments as well as national and regional Aboriginal partners, making it particularly suitable for addressing NWT research priorities and information gaps.

Activities in 2000-2001

The NWTECC met seven times to discuss various contaminants related issues (Table I). Frequent roundtable discussions and updates helped to keep contaminants workers in governments and regional and territorial Aboriginal organizations informed of study results, current activities and upcoming proposals, work and conferences. In addition, to provide an opportunity for committee members to become better informed of recent study results, the NWTECC sent representatives to the annual NCP results workshop in Calgary, Alberta, in September 2000.

The NWTECC held a two-day in-person meeting in February 2001 to review the NCP proposals of immediate relevance to the NWT. Prior to the proposal review, the monitoring, health and communication blueprints were reviewed by the Committee. The Committee also considered Local Contaminants Concerns proposals from communities and approved five for funding in 2000-2001.

Results

The NWTECC provided detailed review and recommendations on 37 NCP research proposals pertaining to the NWT. These recommendations promoted research that

Table 1. Meetings held by the NWTECC during 2000-2001 fiscal year

NWTECC Meeting #	Date	Key Agenda Items
16	April 28, 2000	Review of NWTECC Terms of Reference Selection of Chair and Vice-Chair NCP Management Committee Update Review of Local Contaminants Concerns Project Proposals
17	June 2, 2000	Review of Local Contaminants Concerns Project Proposals GNWT Health Advisories
18	August 22, 2000	Roundtable Identification of Contaminants Issues Communications Planning Review of Local Contaminants Concerns Project Proposals Preparation for NCP Results Workshop
19	Oct.4, 2000	Revision of NWTECC Terms of Reference Results Workshop Roundtable Discussions
20	Nov. 21, 2000	Key Messages Review of Local Contaminants Concern Project Proposals Newsletter Planning
21	Jan. 11, 2001	Human Health and Country Food Monitoring Workshops Development of Key Messages Roundtable
22	Feb. 20-21, 2001	In-Person Review of NCP Proposals

is relevant and socially and culturally appropriate to Northerners. The NWTECC also provided funding for several smaller projects through the Local Contaminants Concerns Fund. These projects studied the following subjects:

- arsenic in berries on mines near Yellowknife
- contaminants in mushrooms
- metals in fish from Gameti (Rae Lakes)
- contaminants in fish from the Peel River

Reports on each of these projects can be found elsewhere in this edition of the *Synopsis of Research Conducted under the* 2000-2001 *Northern Contaminants Program*.

The NWTECC also used the Local Contaminants Concerns Fund to fund the participation of Regional Contaminants Coordinators at a course on contaminants and diseases in wildlife in Saskatchewan in February 2001.

Minutes were produced to summarize the discussions, activities and decisions of the Committee from each meeting. These are available from DIAND Contaminants Division, Yellowknife.

Discussion and Conclusions

In 2000-2001, the NWTECC enabled 16 different Aboriginal and government organizations to coordinate their activities related to contaminants. Based on feedback from the organizations involved, the NWTECC appears to have served well as a two-way communications conduit between community members and national and international programs. It continues to prove itself an effective and inclusive forum for discussing contaminants-related concerns and for providing northern input directly into the NCP.

Expected Project Completion Date

This project is ongoing.

Nunavut Environmental Contaminants Committee

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◆ **Project Team:**

Members of the Nunavut Environmental Contaminants Committee, including representatives from: Department of Fisheries and Oceans, Environment Canada, Inuit Tapirisat of Canada, Kivalliq Inuit Association, Kivalliq Wildlife Federation, Nunavut Department of Health and Social Services, Nunavut Department of Sustainable Development, Nunavut Tunngavik Incorporated, Nunavut Water Board, Qikiqtani Inuit Association, and Qikitaaluk Wildlife Board

Abstract

The Nunavut Environmental Contaminants Committee (NECC) membership is composed of representatives from various departments of the federal and territorial governments as well as national and regional Aboriginal partners. The Committee meets regularly throughout the year to facilitate scientific studies and assessments, the communication of information to Northerners on the presence and possible effects of contaminants in the environment, and the communication of northern priorities to researchers. The NECC met several times this year to discuss various contaminant-related issues, including a two-day in-person meeting to review the Northern Contaminants Program proposals that were relevant to Nunavut.

Key Project Messages

1. The Nunavut Environmental Contaminants Committee (NECC) exists to serve the unique interests and concerns of Nunavut residents with respect to environmental contaminants.
2. The NECC assists in the process of collaborative study, assessment and communication of information to Nunavut residents concerning the presence and possible effects of contaminants in the air, land, water, wildlife and humans.

Objectives

1. Provide a forum for the two-way transfer of contaminants information among Nunavut residents, researchers, the Northern Contaminants Program (NCP) and other contaminants-related initiatives.

2. Facilitate the incorporation of Inuit Qaujimajatuqangit into the study, assessment and communication of environmental contaminants information, concerns and research priorities.
3. Facilitate a communications network that ensures that Nunavut residents are informed of, and involved in, contaminants-related activities.
4. Identify community level priorities and information gaps related to environmental contaminants in Nunavut.
5. Provide updates on research activities in Nunavut that relate to contaminants in the environment, wildlife and people.
6. Act as a clearing house for contaminants information to assist Nunavut residents in making informed decisions about the harvesting and consumption of traditional/country foods.
7. Develop communication strategies to effectively relay information regarding contaminants.
8. Provide advice to communities on appropriate funding sources for contaminants research and remediation projects.
9. Review NCP and other Nunavut related proposals in accordance with the mandate and priorities of the NECC.

Introduction

The NCP is mid-way through its second phase, with more than 10 years of research to date. The program has evolved to include Nunavut communities and regions extensively in research and communication efforts. This has increased the need to have a central body that can coordinate contaminants information and research initiatives. With the formal creation of Nunavut on April 1, 1999, it was important that a separate contaminants committee exist to serve the unique interests and concerns of Nunavut residents. By establishing the NECC, it was hoped that a one-window opportunity for researchers and communities would be provided for their input into contaminants activities and to express their concerns.

During 1999-2000, much work was dedicated to getting the NECC up and running, designing a terms of reference, and making the shift from an interim committee to a formal one. Securing participation and representation from a broad variety of organizations was a primary challenge.

The membership of the NECC is composed of representatives from various departments of the federal and territorial governments as well as national and regional Aboriginal partners, making it particularly suitable for addressing Nunavut research priorities and any information gaps.

Activities in 2000-2001

The NECC met formally four times during 2000-2001 to discuss various contaminants-related issues, including a two-day in-person meeting to review the NCP proposals that were relevant to Nunavut. There were also numerous informal communications throughout the year.

Results

Notes from the four meetings, summarizing the activities and decisions of the NECC, are available from the Chair. Also available are the terms of reference for the Committee.

Discussion and Conclusions

The NECC has proven to be an effective forum for discussing contaminants-related concerns and for providing the NCP with a Nunavut perspective.

Expected Project Completion Date

This project is ongoing.

Yukon Contaminants Committee Communications

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◆ **Project Team:**

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Abstract

The Yukon Contaminants Committee (YCC) was established in 1992 and continues to coordinate research projects operated under the Northen Contaminants Program (NCP). The YCC consists of representatives from government, First Nations, non-government organizations, and private industry. The YCC reviews project submissions under the NCP, for scientific and socio-cultural relevance to Yukon communities, and makes recommendations to the NCP on the suitability of these projects for the Yukon. The YCC also provides a link between research professionals and the Yukon public. The Committee continues to evolve and grow through the addition of partners and changes in its membership. The YCC has remained a diverse and vital partner in Northern scientific research.

Key Project Messages

1. The Yukon Contaminants Committee (YCC) has been active since 1992.
2. The YCC provides direction to, and reviews, research projects to ensure their relevance to Yukoners.
3. Diverse membership on the YCC ensures all aspects of the Yukon community are represented.
4. The YCC continues to grow and evolve with emerging issues and new partners.

Objective

- Ensure that scientific research conducted in the Yukon under the Northern Contaminants Program (NCP) meets the needs of the Yukon while respecting socio-cultural needs.

Introduction

The establishment of the YCC in 1992 was intended to provide the Yukon with an organization that could review research projects that intend to conduct work within the Territory or that affect the Yukon public. The Committee is composed of a diverse group of individuals who represent most aspects of Yukon life. Since that formative year, the Committee has continued to provide direction and support for professionals with an interest in conducting research in the Yukon, and communicating their efforts to the Yukon public. The principal focus of the YCC continues to be ensuring that the research conducted in the Yukon is of relevance to the Yukon public and sensitive to their socio-cultural needs.

The core membership consists of representatives of several federal and territorial departments, the Council of Yukon First Nations, Yukon Conservation Society and Yukon College.

Activities in 2000-2001

The YCC continued to review project proposals at meetings over the year, for submission to the NCP and to act as a link between the research community and the Yukon public. Committee members travelled on behalf of YCC to represent the Yukon at the NCP Annual Results Workshop in Calgary and to the Society of Environmental Technology and Chemistry annual meeting in Tennessee. Committee members also provided communications at local venues, on request. This year saw a number of changes in the composition of the Committee. With the departure of a founding member, Mark Palmer, the long-time Chair, who has moved on to other challenges, the acting Chair is Pat Roach. Ron Pearson, who has also been part of the YCC for some time, will now be representing the Kwanlin Dun First Nation in 2000-2001; Joy Kajiwara has replaced him, representing the territorial government (Department of Health and Social Services). Ruth Hall has arrived to supplement the representation of the territorial government (Department of Renewable Resources). Theresa Kendi, Council for Yukon First Nations, has joined the YCC to assist Cindy Dickson. Nancy Steffen, a member from private industry has joined the Committee. The YCC has also established links with the Yukon River Inter-tribal Watershed Council. The new perspectives brought by private industry involvement and links to a trans-boundary Aboriginal organization will add to the diverse nature of the YCC.

Discussion and Conclusions

All YCC activities are reported to the NCP Management Committee by the Chair at semi-annual meetings.

Expected Project Completion Date

This project is ongoing.

Northern Contaminants Interlaboratory Quality Assurance Program for 2000-2001

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Abstract

This report describes the quality assurance activities conducted during 2000-2001 in support of the Northern Contaminants Program (NCP). Interlaboratory assessments included one study on the analysis of heavy metals and methylmercury in muktuk, Arctic char fillets and burbot liver, and another on toxaphene in standard solutions and a lipid-free burbot liver extract. A third intercomparison on organotins in standard solutions, sediment and biota remains in progress. An investigation was also conducted into the need for assessing the quality of measurement data generated for stable lead isotopes. Lastly, this report also provides a summary of the target analytes and matrices under study during 2000-2001 in NCP-funded research projects.

Key Project Messages

1. Considerable confidence can be placed in the reliability of data generated for the toxic heavy metals arsenic, cadmium, copper, mercury, selenium and zinc, while aluminum, chromium and nickel data show more variability between laboratories.
2. Methylmercury and total organic mercury data remain very comparable among the NCP measurement laboratories.
3. Organochlorine pesticides (OCs) and polychlorinated biphenyls (PCBs) are generally accurate and comparable at analyte concentrations > 1 $ng{\cdot}g^{-1}$.
4. Because of the diversity in standards and quantitation techniques, toxaphene data should be scrutinized carefully, particularly those of total toxaphene measurements.

Objectives

The main objective of the NCP QA Program is to provide information on the overall quality of the NCP's measurement data to its science managers in order that they may make informed decisions on the sources and effects of contaminants on the Arctic environment and on human health. As a result, these decision-makers would be assured that their contributions toward the establishment of international agreements and controls to protect the health of the Arctic ecosystem and its inhabitants are based on a scientifically sound database of information.

A second objective is to provide the research managers of the NCP-funded studies, assurance of the quality, reliability and comparability of measurement results produced by laboratories contributing data to their research. This is primarily achieved by conducting intercomparison exercises on various contaminants of concern, such as persistent organic pollutants (POPs) and heavy metals.

Specifically, the goals for 2000-2001 were to:

1. Maintain an inventory of measurement capabilities and interests among the NCP laboratories in order to provide advice to the QA Technical sub-Committee on the status of the NCP's QA needs, on emerging issues, such as new contaminants of concern, and on changes in priority.
2. Propose, coordinate, and review participation by NCP laboratories in external national and international intercomparison exercises, where such participation would be considered to be more cost-effective and would add value to this QA Program.
3. Conduct an interlaboratory study on the analysis of toxaphene in standard solutions and a lipid-free burbot liver extract.
4. Conduct an interlaboratory study on the analysis of toxic heavy metals including mercury, arsenic, cadmium and selenium and on methylmercury in muktuk, Arctic char and burbot liver tissue.
5. Conduct an intercomparison on organotin measurements.
6. Investigate the need for assessing the quality of measurement data for stable lead isotope measurements in the NCP research studies.

Introduction

The NCP requires an ongoing QA program that monitors, assesses and reports on the quality and comparability of measurement results being generated within its research projects. It is designed to identify sources of measurement uncertainties and variation of analytical results in order to provide information on data quality and reliability to the management of the NCP. Also, by serving as a diagnostic tool for the participating analysts, this QA program provides a means for continual improvement in the measurement process.

The main activities are the intercomparison exercises, focusing on contaminants of concern to Canada's Northerners. Participation in these studies ensures that laboratories conducting measurements for the NCP are producing reliable data with acceptable levels of precision and accuracy, and ensures comparability among the various research and analytical laboratories and between the NCP research projects.

The submitted laboratory data for both standard solutions and matrix test samples are evaluated for accuracy and comparability by Z-scores and by comparison to the target concentrations. Precision is evaluated by means of replicate analyses, by percent difference on blind duplicate samples, or by graphical interpretation of Youden Pair plots (Youden 1959). Finally, bias (a systematic error) is determined by a modified Youden ranking procedure. The data assessment can then be used as a diagnostic tool for the participants to apply corrective action, as needed. In addition, where possible, the data set for the NCP QA studies is compared to the results of other similar external intercomparisons. Thus, the complete study report provides a snapshot of data quality to the science managers of the NCP along with an overview of the capabilities and comparability of the NCP laboratories conducting these measurements.

Activities in 2000-2001

Trace metal and methylmercury intercomparison study

The first interlaboratory study during 2000-2001 was conducted on the analysis of trace metals and methylmercury in biota. Three frozen, homogenized tissue samples, including narwhal muktuk, burbot liver and landlocked Arctic char muscle, were shipped to 15 participating laboratories for the analysis of heavy metals, including arsenic, selenium and mercury, and for methylmercury. As in a previous study, it was anticipated that approximately one-third of the participants would report concentration levels of the methylmercury species, while an equal number would report "Total Organic Mercury" in the test samples.

Toxaphene intercomparison study

The toxaphene methodology review conducted during 1999-2000 revealed a very diverse set of instrumental and quantitation techniques as well as many types and sources of calibration standards being used by the NCP measurement laboratories. Therefore, to eliminate differences in standards as the primary source of variation between laboratories, this first NCP toxaphene intercomparison included the provision of a calibration standard which the participants were to use as their calibration solution for the analysis of toxaphene congeners. In addition, they were asked to provide a chromatographic and quantitative analysis of their usual calibration solution against this standard. The four check samples in this study included one test solution of 13 toxaphene congeners, two technical toxaphene standards for total toxaphene analysis, and one lipid-free burbot liver extract for congener-specific and total toxaphene analysis. The samples were shipped to 12 laboratories and one set of data remains outstanding.

Organotin intercomparison study

The current information (Table 1) indicates that only one research project had proposed to include the analysis of organotins in their work. Therefore, several additional laboratories were invited to participate in an intercomparison study which was delayed until all facilities had their methodologies on-line. Seven test samples (two standard solutions, three sediment and two biota) were shipped to eight laboratories in March 2001 and

Table 1. Target analyses for NCP projects in 2000-2001[1]

Project No.	Project Leader	Agency	Matrix	Hg	Other TMs	MeHg	RNs	OCs / POPs	PCBs	Toxaphene
H-1, H-3, H-4, H-10	Ayotte Dewailly Muckle	CTQ	human tissues	•	Se	•		•	•	
H-5	Chan	CINE	rats			•				
H-16	Bondy	HC-BCS	rats					•		
M-1	Stern	FWI	burbot	•	Se, As			•	•	•
M-19			beluga					•	•	
M-2	Lockhart	FWI	fish	•						
M-22			whale, walrus	•						
M-3	Norstrom	NWRC	polar bears					•	•	
M-4	Braune	NWRC	seabird eggs	•				•	•	
M-5			oldsquaw	•	•					
M-24			fox	•	•			•	•	
M-25			air, water					•		
M-6	Wayland	CWS	eiders	•	•					
M-7	Muir	NWRI	char	•	•	•		•	•	•
M-20			seals, walrus	•	•	•		•	•	•
M-8	Evans	NHRI	fish	•	•			•	•	•
M-9			fish	•	Se, As					
M-10	Elkin	GNWT	caribou	•	•		•			
M-12	Roach	DIAND	burbot, salmon					•	•	
M-13	Bidleman	MSC	water, sediment, air, beluga, seal					•		•
M-14	Blanchard	MSC	air					•	•	
M-15	Schroeder	MSC	air, snow	•						
M-32			air	•						
M-16	Poissant	MSC-QC	air	•						
M-29	Cheam	NWRI	sediment	•	•					
M-31	Macdonald	IOS	water, sediment	•				•	•	•
TOTALS				**18**	**11**	**4**	**1**	**15**	**12**	**6**

[1] Additional parameters being measured in the NCP-funded research projects include PBBs, BDPEs, dioxins/furans and stable isotopes (Projects M-1 and M-19), organotins (Project M-20), PAHs (Project M-14) and PCNs (Project M-13).

the target date for submitting results has been set for June 30, 2001.

Stable lead isotope review

A brief literature review of stable lead isotope measurements in environmental and biotic media was conducted. The need for conducting an NCP intercomparison study was based on the current state of quality control in laboratories conducting such analyses and on the certified reference materials (CRMs) and external quality assessments available to these facilities.

Results

Update to the NCP laboratory and research project survey

Table 1 provides a summary of the NCP-funded research projects containing a measurement analysis component. For 2000-2001, 29 research projects, involving 20 project leaders, employed the use of 22 measurement facilities plus two remote (on-site) monitoring locations in Alert, Nunavut and Amderma, Russia. The most common matrices for analysis were marine or terrestrial mammals (9 studies) and fish (6 studies). Three studies measured contaminants in Arctic birds or eggs, and four included human tissue samples (blood, urine or hair) in their research. Eight studies continued to address abiotic samples, such as air measurements (6 studies), water or snow (4 studies), and sediment (3 studies).

The inorganic contaminants being measured in the NCP-funded studies were: mercury (18 studies), other toxic heavy metals (11 studies), and methylmercury (4 studies). This year, only one study proposed analyzing for organotins and one for measuring radionuclides. Among the organic parameters of interest, OCs were measured in 15 research projects, PCBs in 12 studies, and toxaphene in 6 studies. Dioxins and furans, organobromine compounds and polychlorinated naphthalenes (PCNs) were each listed in one study.

External QA programs

Several of the NCP measurement laboratories participate in a variety of other external QA programs on an ongoing basis, such as the radionuclide intercomparisons by the International Atomic Energy Agency, the toxaphene development exercises conducted by the Quality Assurance of Information for Marine Environmental Monitoring in Europe (QUASIMEME), and special studies such as that for brominated diphenyl ethers (BDPEs), offered by researchers in the Netherlands in collaboration with the Bromine Science and Environmental Forum (de Boer and Cofino 2000). In addition, many of the NCP measurement laboratories are accredited by and participate in the Canadian Association for Environmental Analytical Laboratories (Ottawa, Ontario) environmental performance evaluation studies.

Interlaboratory Study NCP-II-4: toxaphene in standard solutions and extracts

The results for the toxaphene intercomparison are very encouraging, particularly for the congener-specific analyses. The coefficients of variation for the individual (non co-eluting) toxaphene congeners in the blind test solution ranged from 7% to 25%, showing very good agreement among the 10 laboratories. For the eight participants that provided results for Parlar 26, 38, 42, 44, 50 and 62 in the burbot liver extract, the between-lab comparabilities ranged from 16% to 69%. Few data were reported on other congeners because of the low concentration levels in this sample.

There was less agreement between laboratories for total toxaphene, although this could be due to the provision of a calibration solution for congener-specific analysis. The two technical toxaphene standards had coefficients of variation of 48% and 43%, and the data for total toxaphene in the burbot liver extract had a coefficient of variation of 56%. Interestingly, the distribution of results appeared bimodal in nature for both of the technical toxaphene standards and the resultant interlaboratory means and medians were significantly lower than the target values assigned by the supplier of this standard. Either the majority of laboratories are underestimating their total toxaphene measurements or the reported concentration of this particular commercial standard was incorrectly identified. Despite the poor interlaboratory comparability, a plot of the two test samples as Youden pairs (Youden 1959) revealed that the intralaboratory precision for total toxaphene was very good for all participants.

Our previous toxaphene survey indicated that several researchers were quantifying total toxaphene against a Hercules technical toxaphene standard, while others employed technical toxaphene standards from the United States Environmental Protection Agency or other (commercial) suppliers. Most calculated total toxaphene by using a single response factor against the sum of four to more than 40 peak areas, while two used multiple response factors for some or all of their total toxaphene calculations. In this study, eight participants analyzed their samples by gas chromatography mass spectrometry (GC-MS), two used GC-MS-MS Ion Trap, one used GC-MSD (mass selective detector) and GC- ECD (electron capture detection), and one used GC-ECD with a microbore column. Full details of the analytical and quantitation techniques can be found in the study report.

Interlaboratory Study NCP-II-5: trace metals in biota

Three frozen, homogenized tissue samples were shipped to 15 participating laboratories for the analysis of toxic heavy metals and methylmercury. The test samples were narwhal muktuk from the Iqaluit region in Nunavut, fillets of landlocked char from North Lake near Resolute, Nunavut, and burbot liver from the Old Crow, Yukon, and Fort Good Hope, NWT, areas. Fourteen sets of results were received for the trace metals, four laboratories provided methylmercury data and another four laboratories reported data for total organic mercury.

The test samples in this study were particularly challenging: the muktuk was difficult to homogenize and digest, the char and burbot liver had very low concentration levels of many of the target metals, and the muktuk and burbot liver were relatively high in lipid content. Nevertheless, for most of the key metals (arsenic, cadmium, copper, iron, mercury, manganese, lead, selenium and zinc), the data were fairly comparable as demonstrated by coefficients of variation < 30%. The exceptions for these metals occurred where the concentration levels were within 10-fold of the method detection limits of the participating laboratories. The least comparable metals were chromium and nickel where the interlaboratory coefficients of variation ranged from 54% to 63% in all three samples. As a result of the very low levels, there were several outliers in this study and consequently, several unsatisfactory Z-scores (i.e. $Z > 3$). However, most participants achieved better than 70% satisfactory Z-scores. Only three participants exhibited any metal-specific bias: one was biased high for arsenic and manganese, one was biased high for mercury and a third participant was biased high for selenium. This is a considerable improvement over the first trace metal study for Phase II of the NCP, where all participating laboratories exhibited bias for the analysis of at least one heavy metal.

The total mercury and total organic mercury results showed very good agreement among laboratories for the muktuk and the char samples. With the exception of the very low level burbot liver tissue, where there were wider ranging results and several 'non-detects', the coefficient of variation did not exceed 16% for any of the test samples. Among the four laboratories that reported methylmercury results, three were in excellent agreement while the fourth, which is not presently reporting methylmercury data to the NCP, was erratic with both high and low results relative to the other data.

Interlaboratory Study NCP-II-6: oganotins in sediment and biota

The toxic impact of tributyltin (TBT) on marine organisms has become well-known (Chau et al. 1997), and its discovery in harbour sediments and snails from Norway, Iceland and Alaska, including some from remote regions, has made it a contaminant of increasing concern (Arctic Monitoring and Assessment Programme 1998). It is released into the environment by the leaching of TBT-based anti-fouling paints used on boats and ships. Because the data on TBT levels in the Arctic are limited, the Arctic Monitoring and Assessment Programme (AMAP) made the following recommendations (Arctic Monitoring and Assessment Program 1998):

- "Surveys of TBT in harbour sediments in the Arctic should be carried out to assess the extent of TBT contamination."
- "The risk exists that TBT biomagnifies and analyses should also be made on bottom-feeding fish, waterfowl, and marine mammals, particularly as these are components of the diet of Arctic peoples."

Although only one NCP research project had proposed to incorporate the analysis of organotins in its work, eight facilities were invited to participate in an intercomparison study. The seven test samples include two standard solutions, three dried sediments and two dried biota samples. The analysts have been asked to report on the concentration levels of monobutyltin trichloride, dibutyltin dichloride and TBT chloride. This study is currently in progress.

Stable lead isotope measurements

In this year's annual survey, no NCP project leaders identified the measurement of stable lead isotopes as being a component of their current research. However, past NCP studies have reported on these measurements (Lockhart et al. 2000) and they are becoming increasingly popular in global studies of climate change and contaminant source identification (Kurkjian et al. 2000, Murphy and Katz 1998).

The measurement of environmental isotopes is a powerful tool that can be used to identify contamination sources and pathways, to investigate climatic changes, and to study environmental forensics (Murphy and Katz 1998), human exposure and metabolism (Smith et al. 1996, Smith et al. 1997). This is because isotopes, both stable and radioactive, are preserved in various natural archives such as lake and ocean sediments, glaciers, polar ice caps, precipitation and oceans, and even trees. Ratios of stable isotopes are often uniquely associated with a geologic formation, while certain naturally occurring processes can concentrate the abundance of one type of isotope in one location as compared to another. Lead's isotopic abundance is one of the least reproducible because various isotopes are the final products of the radioactive decay of a number of heavy elements (Woolard et al. 1998). The subtle changes in the concentration or type of isotopes can be accurately measured and compared to reconstruct an accurate history or to provide evidence of anthropogenic inputs of contaminants, such as lead from leaded gasoline.

Until the mid- to late 1990s, most studies employing stable lead isotope tracer methods used thermal ionization mass spectrometry (TIMS) to measure isotope abundance. This technique provides excellent isotope measurement sensitivity and precision, but is expensive, labour-intensive and not well suited for rapid throughput of large numbers of biological samples (Gwiazda et al. 1998). More recently, scientists have explored the use of ICP-QMS (inductively coupled plasma quadrupole mass spectrometry) for measurements of lead isotopic ratios in environmental work. Recognized limitations to ICP-MS measurements include the inability to measure very low levels of lead and particularly the low abundance isotope ^{204}Pb (Delves 1999), a relatively noisy sample introduction, spectroscopic interferences and insufficient precision to adequately distinguish environmental sources based upon their isotopic composition (Sardella, personal communication). In the case of lead, the isotope ratios of contaminant environmental lead typically vary in a narrow range (e.g. < 3% to 7%). For ICP-QMS the general precision of measurement is considered to be 2% to 3%, with a precision on isotope ratios of 0.1% to 1% (Sardella, personal communication, Moens and Jakubowski 1998). The use of high resolution technology, such as the double-focusing mass spectrometer, which can greatly improve the sensitivity and precision, is now becoming more common. A single-collector double focusing magnetic sector ICP-MS can achieve precisions of 0.05% to 0.2%, and when a multi-collector detection system is used, precision can be further improved to a level comparable with that of the more costly TIMS (Moens and Jakubowski 1998). Therefore, it is becoming increasingly important to assess the precision and accuracy of stable lead isotope data by considering the limitations of the instrumentation used (Smith, personal communication).

There are, at present, no known external quality assessment programs for stable lead isotope measurements. Few CRMs are known to be commercially available. The National Institute for Standards and Technology has three lead wire CRMs available as follows:

- SRM-981: Common Lead Isotopic Standard
- SRM-982: Equal-Atom Lead Isotopic Standard
- SRM-983: Radiogenic Lead Isotopic Standard

Each has certified isotopic compositions for ^{204}Pb, ^{206}Pb, ^{207}Pb and ^{208}Pb and for the atomic abundance ratios of ^{204}Pb/^{206}Pb, ^{207}Pb/^{206}Pb and ^{208}Pb/^{206}Pb.

Therefore, when stable lead isotope measurements have a greater role in the NCP research studies, it is recommended that method performance be carefully documented with all data. Furthermore, precision and accuracy of such analyses should be established and monitored internally by the laboratories with the above CRMs, and externally by the NCP or other external QA providers, in appropriate intercomparison studies.

Discussion and Conclusions

Quality assurance and quality control are essential elements of all research and monitoring programs. Ongoing interlaboratory comparison studies provide assurance on the quality and reliability of data being generated and on the comparability of measurement results between laboratories. Without this assurance of data quality and comparability, the value of measurement information upon which decisions are made will be lost. It is imperative that managers and decision makers of the NCP have a scientifically sound science base upon which to make their decisions.

The results of this third trace metal/methylmercury intercomparison indicate that considerable confidence can be placed in the data being generated for most of the key toxic heavy metals. Chromium and nickel data, however, remain less reliable as the data were significantly less comparable over a wide concentration range. Despite the difficulty of digesting the muktuk sample, results from the different laboratories were generally in good agreement; however, for the lower concentration char and burbot liver samples, some laboratories had difficulty generating good results. On the other hand, the methylmercury and total organic mercury results remain very reliable for the NCP measurement community. Continued monitoring of trace metals and methylmercury analyses shall continue on an annual basis, incorporating new test materials such as caribou liver, seal kidney and additional fish tissues.

The overall performance and comparability of the NCP laboratories in the toxaphene intercomparison were very encouraging. However, there also were indications that significant differences remain between the laboratories, particularly for total toxaphene data. To ensure comparability with other international programs that address toxaphene, the selection of target parameters for future studies will continue to follow the AMAP recommendation (Arctic Monitoring and Assessment Programme 1998) that "Future monitoring should ... include determination of total toxaphene (by NIMS) for comparison with past work as well as measurements of specific chlorobornane congeners." Therefore, the next toxaphene intercomparison will again focus on separation and identification of individual congeners, and on the quantitation of total toxaphene. The study samples will include standard solutions to assess accuracy as well as more complex matrix samples.

Recommendations for the NCP interlaboratory QA program remain as before:

1. Annually assess the data quality of trace metal analyses, including those for mercury, methylmercury and selenium, primarily in biotic samples.
2. Conduct interlaboratory studies for OCs and PCBs every 2 years, including parameters such as the hexachlorocyclohexanes (HCHs), chlordanes, and PCB congeners at appropriate levels in both biotic and abiotic samples.
3. Conduct annual toxaphene intercomparisons specific to the NCP research projects, focussing initially on comparability of standards, congener identification and quantitation of total toxaphene in standards and extracts, and then progressing to more complex matrix samples as the intercomparability improves.
4. Address the quality and comparability of measurements for stable lead isotopes, organotins, dioxins, PAHs and any emerging contaminants of concern, as needed.
5. Maintain a small repository of surplus check samples and standards with known target concentrations that can be made available to NCP laboratories that experience difficulties with the study samples and require additional test material to evaluate the success of their corrective actions, and to those who wish to test new or modified methodologies. The development of reference materials, as recommended by AMAP (Arctic Monitoring and Assessment Programme 1998), through the interlaboratory studies should also be considered.

The intercomparison exercises will continue to be the main activities of this QA program. Other activities, such as a maintaining an inventory of laboratory capabilities and external sources of QA support such as pertinent intercomparisons and reference materials, are also important to achieve the goals of this program. The combination of these efforts will not only provide for an evaluation of data quality within the NCP and to other international programs, but will also provide a means for continual improvement in the measurement process for the laboratories involved.

Expected Project Completion Date

As recommended by the QA Technical Sub-Committee, the NCP laboratory survey will be updated annually prior to their review of the proposal for the next year's QA program. Also, external QA programs will be reviewed on an ongoing basis in order to notify the appropriate NCP laboratories of pertinent intercomparisons for their analyses.

For various reasons, the test materials for the interlaboratory studies were not received until mid-summer through early fall 2000. Therefore, the studies were initiated and concluded later than usual. The preliminary data review for the trace metals study was provided to the participants in April 2001 and a final data summary will be issued by August 2001.

The preliminary data review for the toxaphene intercomparison will be sent to the participating laboratories in May 2001, as soon as the final set of data is received. A final report discussing the accuracy and comparability of both congener and total toxaphene measurements will be issued by August 2001. This report will also include a detailed comparison of the various calibration standards, quantitation techniques and instrument methodologies being used.

Results for the organotin intercomparison are expected by June 30, 2001. The preliminary data summary will be issued in July and a final report will be completed by September 2001.

The assessment of analytical comparability is an ongoing process, with three new intercomparisons being scheduled for 2001-2002. The test samples for Interlaboratory Study NCP-II-7 on the analysis of trace metals and methylmercury in caribou liver, ringed seal kidney and liver, and Greenland shark muscle will be shipped in May 2001, as soon as all test materials become available. Interlaboratory Study NCP-II-8 on OCs and PCBs in seal and polar bear blubber, seabird liver and fish tissues is targeted for distribution in July 2000, along with a brief survey on the calculation and reporting of PCB blanks. Study NCP-II-9 on toxaphene will also be conducted this fiscal year, with sample delivery being targetted for September 2001.

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